ABSTRACT

BOWLING, BRANDY LEIGHLYN. An Investigation of the Characteristics and Sources of Pedagogical Content Knowledge in Community College Biology Instructors. (Under the direction of Dr. Soonhye Park).

Research has shown that pedagogical content knowledge (PCK) is a key component in shaping teacher practice and positively influencing student learning outcomes. However, community college faculty rarely have formal pedagogical training which provides them opportunities to develop their PCK and pedagogical knowledge because they are only required to have post-baccalaureate degrees in the content area they are expected to teach, not educational preparation. Considering this, the nature of PCK in community college professors might be different from K-12 teachers. Since a majority of PCK research use K-12 classroom settings, little is known about college professors' PCK. In this regard, this qualitative research study investigated the characteristics and sources of PCK development of four community college biology instructors.

Main data sources included interviews, observations, and researcher's field notes. Data were analyzed using multiple approaches including the constant comparative method, analysis using a priori codes, and the PCK mapping approach.

As a result of the analysis, several themes emerged that addressed three research questions pertaining to the characteristics of PCK, the relationship between content knowledge and PCK, and sources of PCK development in these participants. First, three themes related to PCK characteristics revealed teacher-centered orientations, less sophisticated overall PCK, and time as a limiting factor of PCK. These three themes are discussed in relationship to orientation towards science, student responsibility, and limited applications of assessment strategies.

Next, two themes described the relationship between content knowledge and PCK, including no significant impact of content knowledge on overall PCK or the individual components of PCK and their interactions. These two themes are explored to identify potential ways to develop PCK in the context of community college biology instructors.

Finally, two themes associated with sources of PCK development revealed a strong utilization of online and publisher-developed sources and a poignant interest in relevant professional development. Again, these two themes were discussed in relation to the design and implementation of relevant professional development targeting PCK development specific to the context of community colleges.

Based on the findings in this study, community college administrations are strongly encouraged to support relevant professional development for faculty across disciplines. The results in this study provide implications for professional development specific to community college science faculty to improve PCK that enables them to design positive STEM experiences and improve student learning outcomes. In particular, professional development on the effective use of student-centered learning activities and formative assessment techniques can lead to better student learning outcomes by allowing multiple opportunities to identify and address specific knowledge gaps before students complete summative assessments.

An Investigation of the Characteristics and Sources of Pedagogical Content Knowledge in Community College Biology Instructors

by
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DEDICATION

This dissertation is dedicated to my parents, Michael and Denise Bowling. Thank you both for all of your love, support, and advice throughout the years. You gave me courage to pursue my dreams and find my place in the world. I wouldn't be the person I am today without your guidance. And thank you to my brother, Adam, for all the adventures throughout the years. I love you all very much!

BIOGRAPHY

Brandy Leighlyn Bowling was born and raised in a small community in central North Carolina. Her parents instilled a love for nature at an early age, which eventually blossomed into a passion for biology. She earned her Bachelor of Science degree in Biology from the University of North Carolina at Chapel Hill in 2000. She matriculated into the University of North Carolina at Greensboro and completed her Master of Science degree in Biology in 2002. During her graduate studies, her research efforts centered around the effects of Epstein-Barr virus on nuclear proteins known as promyelocytic leukemia bodies. During this time, she also served as a teaching assistant for undergraduate biology labs. This is when she first discovered her passion for teaching, and was recognized at graduation with a Teaching Assistant Award in Biology.

However, against the advice of her graduate committee to remain as an instructor, Brandy decided to put her newly learned research skills to use and pursued a career in medical research. She worked as a Research Analyst at Duke University Medical Center for seven years. During this time, she researched genetic corneal diseases and genetic kidney disorders. Eventually, Brandy decided that she missed the excitement of seeing the illumination of understanding in the eyes of her biology students. Hence, she decided to return to her teaching career. She wanted to learn the best practices for science teaching to inspire a love of biology in her students the way her parents had for her. Therefore, she decided to pursue her Doctor of Philosophy degree in Science Education at North Carolina State University. During this time, she worked as a Teaching Assistant in the Biology Department followed by a position as an adjunct Biology instructor at a local community college. Currently, she continues to work at a community college as a full-time biology instructor.

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First, I would like to acknowledge my family, friends, and colleagues for all their love, support, and patience throughout my journey. You all have lifted my spirits with your kind words and loving support during this process. I would also like to sincerely thank my participants; your invaluable insights about community college education has made this one interesting journey.

Next, I would like to thank Dr. Meg Blanchard, Dr. Aaron Clark, and Dr. James Minogue for their endless guidance and patience throughout my pursuit of this science education degree. You have all supported me as I struggled to embrace my inner qualitative educational researcher. I would also like to acknowledge the many years of guidance from Dr. Patricia Simmons, who supported me tirelessly through slow progress, and who eventually guided me to my current advisor, Dr. Soonhye Park. I would also like to thank fellow graduate student Mr. Vance Kite for his qualitative coding skills, and Ms. Christy Buck for all of her wonderful administrative support and patience in answering my never-ending questions.

Finally, I owe much gratitude to Dr. Soonhye Park for igniting in me a passion for PCK as well as her unlimited guidance, support, encouragement, and patience during my research and dissertation progress. I am forever grateful to everyone for their never-ending guidance and support I have received during my time in this program.

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CHAPTER 1

INTRODUCTION

Recently, the President's Council of Advisors on Science and Technology (2012) reported the inadequate number of graduates in the United States with post-secondary degrees in science, technology, engineering, and mathematics (STEM) fields of study. Leaders in business and industry have also indicated concerns about sufficient numbers of graduates with baccalaureate and associate level degrees to maintain and improve the United States' global competitiveness in STEM areas (Malcolm & Feder, 2016).

According to the National Science Board (2014) and the National Center for Education Statistics (2013), there continues to be a growing interest in STEM among high school graduates planning to attend a 2-year or 4-year institution. However, 6-year completion rates for STEM degrees remain noticeably lower (i.e., 40%) compared to the completion rates among all students (i.e., 56%) who first enrolled in 2007 (President's Council of Advisors on Science and Technology, 2012; Shapiro, Dundar, Ziskin, Yuan, & Harrell, 2013). The President's Council of Advisors on Science and Technology (2012) also reported the majority of students intending to pursue a STEM major do not earn a degree in these fields, and most students who changed majors do so after participating in an introductory course of mathematics, science, or engineering. It is important to understand why students interested in STEM degrees are leaving the STEM field.

Research by Brainard and Carlin (1998) and Seymour and Hewitt (1997) suggest that many students who performed well in STEM-related introductory courses and were capable of earning STEM degrees still decided to switch to non-STEM majors. More recently, Malcolm and Feder (2016) asserted, "the population of those who complete STEM degrees is … the result of the cumulative effects of students' individual decision making in response to factors in their institutions (e.g., quality of teaching, availability of support structures, discovery of attractive alternative majors) and external factors (e.g., early educational preparation, financial concerns, and larger social issues that affect specific groups)" (p. 32).

The Role of Community Colleges in STEM Education

Community colleges are typically 2-year institutions that offer a large variety of degree programs, including a number of pathways in STEM for both high-skill and middle-skill jobs. Community colleges are cost-effective, more accessible to everyone, and serve a diverse population of students. Community colleges offer two major categories related to STEM education, including transfer programs and technical programs. Transfer programs include science, engineering, and mathematics programs that prepare students to transfer to 4-year institutions in order to pursue a bachelor's degree or higher in STEM-related fields. Technical programs include occupational programs with the primary goal to prepare students with the knowledge and skills required to enter the workforce in STEM-related fields.

According to the National Center for Education Statistics (2014), 2-year students accounted for 40 percent of all undergraduate enrollment in 2012. Additionally, van Noy and Zeidenberg (2014) found that about half of community college entrants in 2003-2004 were enrolled in a STEM-related field at some point during their educational pursuits. These statistics show the potential of community colleges to expose a significant number of students to STEM courses. Community colleges primarily offer introductory STEM courses which are transferable to 4-year programs. Since the President's Council of Advisors on Science and Technology (2012) reported most students who changed majors do so after participating in an introductory course of mathematics, science, or engineering, then community colleges have a great opportunity to provide students with positive STEM experiences in introductory courses that may encourage them to complete STEM-related degrees. Malcolm and Feder (2016) concluded "that community colleges play a substantial role in addressing workforce needs and in further developing the talent pool of students who may later obtain advanced STEM degrees" (p. 40). Despite its' important role in STEM education, post-secondary STEM research in community colleges is limited compared to its' 4-year counterparts (Labov, 2012). This study contributed to the limited research base by exploring the pedagogical content knowledge of biology faculty at community colleges and its potential impact on students' success in course completion of biology courses.

Issues in Community Colleges

The American Association of Community Colleges (2012) identified several current issues with community colleges including low completion rates, transfer students' unpreparedness for the rigors of higher education, wide skills gap between students and workforce needs, undefined or outdated mission statements, low collaboration between community colleges, lack of community support, and unproductive results. In particular, low completion rates are a concern.

The American Association of Community Colleges (2012) reported that less than half of all community college students have graduated or transferred to a 4-year institution within six years of initial enrollment. Among these students, Malcolm and Feder (2016) assessed that "about 20 percent of STEM community college students attained any STEM credential 6 years after enrollment" (p. 49). However, it should be noted that community college students have a variety of educational goals. They may choose to earn a 2-year associate's level degree, transfer to a 4-year institution (with or without earning the 2-year degree), earn a certificate or diploma, or learn job-related skills (Malcolm & Feder, 2016). Due to these various intentions, van Noy and Zeidenberg (2014) insisted that multiple measures of community college STEM outcomes were necessary to assess the success of community college students' outcomes, not just a single focus on degree completion. Rassen, Chaplot, Jenkins, and Johnstone (2013) further asserted that these multiple measures should include degree/credential completion, degree/credential attainment at other institutions, continued enrollment, and employment. As the American Association of Community Colleges (2012) concluded, *"If community colleges are to contribute powerfully to meeting the needs of 21st century students and the 21st century economy, education leaders must reimagine what these institutions are – and are capable of becoming" (p. vii).*

Role of Faculty in Community Colleges

One of the major goals of community colleges is providing access to education for everyone. Therefore, anyone who wants to pursue additional education is accepted into the community college. According to Rifkin (2017), "this open-access mission places the responsibility of student success in the hands of the faculty." In order for students with such a wide range of abilities, interests, and goals to be successful, a student-centered approach to education is necessary (National Science Board, 2010). Hence, community college faculty spend 15 hours or more of their time teaching and a majority of the remaining time preparing for instructional time and working with students outside of the classroom. Rifkin (2017) asserted that "community college faculty register more student contact hours than any other educational sector."

Community college faculty face challenges with this combination of heavy teaching loads and academically-challenged student populations (National Science Board, 2010). Although they are dedicated to excellence in teaching, many community college faculty are only required to have a master's level degree in the content area they teach; many of them do not have any formal pedagogical training or education. This lack of pedagogical education can be seen in their selected modes of instruction and assessment. Rifkin (2017) found that in order "to contend with large numbers of students, community college faculty rely heavily on lecture and lecture-discussion as the dominant modes of instruction. [Additionally,] to contend with the less-than-college-level literacy skills of students, instructors use multiple-choice exams instead of essays or other forms of writing assessment." Rifkin (2017) concluded, "The pedagogical demands of an open-access institution can be frustrating and require more attention as the community college student population becomes more varied. Maintaining faculty satisfaction and vitality while striving to meet societal demands for educational opportunity for all who can benefit will be a tough task, but the future of the community college as a corridor of educational opportunity depends on it."

Pedagogical Content Knowledge

Shulman (1986) first described pedagogical content knowledge (PCK) as knowledge "which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge *for teaching* … the particular form of content knowledge that embodies the aspects of content most germane to its teachability" (p. 9). He further clarified PCK as "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman, 1987, p. 8). In his initial discussions of PCK, Shulman (1986) described several dimensions that fall within the category of PCK including useful forms of representations and the recognition of student misconceptions with "the instructional conditions necessary to overcome and transform those [misconceptions]" (p. 10).

Since Shulman first described PCK, research efforts have focused on the positive correlation between teacher PCK and improved student learning outcomes in STEM areas at the K-12 education level (Ball, Thames, & Phelps, 2008; Baumert, et al., 2010; Gess-Newsome, 2013; Gess-Newsome & Ledermann, 1995; Hill, Rowan, & Ball, 2005; Keller, Neumann, & Fischer, 2017). Research findings by Ball et al. (2008), Baumert et al. (2010), and Hill et al. (2005) indicated positive effects of teacher PCK on student learning and achievement in secondary mathematics courses. Keller et al.'s (2017) study of 77 secondary physics teachers in Germany and Switzerland found that teacher PCK positively predicted students' achievement. Finally, multiple research studies by lead researcher Gess-Newsome (2013) has repeatedly shown the correlation of teacher PCK on increased student achievement in secondary biology courses.

Taken together, it is evident that PCK is a key component in shaping teacher practice and positively influencing student learning outcomes in primary and secondary (K-12) education (Ball et al., 2008; Baumert, et al., 2010; Gess-Newsome, 2013; Gess-Newsome & Ledermann, 1995; Hill et al., 2005; Keller et al., 2017). In this regard, K-12 teacher education programs place a great emphasis on developing PCK in addition to content knowledge and pedagogical knowledge (Park & Oliver, 2008a). However, community college faculty rarely have formal pedagogical training which can provide them opportunities to develop their PCK as well as their pedagogical knowledge. Community college faculty are only required to have a master's level degree in the content area they teach, and most science faculty at 4-year institutions are expected to have a doctorate level degree in the content area they teach. Given this significant difference in teacher education, preparation, and training between K-12 teachers and community college science faculty, one cannot assume that what research tells us about how K-12 teachers develop

PCK and how their PCK impacts student learning is directly applicable to community college faculty. Therefore, it is important to provide an in-depth examination of PCK in community college faculty in order to provide insights into how to best support their PCK development.

Relationship Between Content Knowledge and PCK

Considering the importance of PCK in teaching practices and student learning outcomes, researchers have devoted their efforts to identifying factors that influence PCK development. Some researchers argued for the relationship between teacher PCK and years of teaching experience, professional development, and mentorship (Appleton, 2008; Hanuscin, Menon, Lee, & Cite, 2011; See, 2014; van Driel & Berry, 2012; van Driel, Verloop, & de Vos, 1998). van Driel et al. (1998) identified years of teaching experience (with adequate content knowledge) as a major factor that impacts PCK in science teachers. van Driel and Berry (2012) asserted that professional development programs designed to develop teacher PCK "should be closely aligned to teachers' professional practice and, in addition to providing teachers with specific input, should include opportunities to enact certain instructional strategies and to reflect, individually and collectively, on their experiences" (p. 26). Appleton (2008), Hanuscin et al. (2011), and See (2014) showed the significant impact of mentorship on PCK in secondary education.

Meanwhile, there are only a few research studies that indicated the important role of content knowledge in shaping PCK. For example, Özden (2008) completed a case study of twenty-eight science student teachers in Turkey who were asked to prepare a lesson about phases of matter, complete a test of their content knowledge, and participate in an interview discussion of their content knowledge, PCK, difficulties in lesson planning, anticipated problems in teaching, and their perceptions of the educational needs in order to be a successful teacher. As a result, Özden (2008) found "that content knowledge had [a] positive influence on pedagogical content knowledge and effective teaching" (p. 637). Krauss et al.'s (2008) quantitative research study of 198 secondary mathematics teachers in Germany also showed a strong relationship between content knowledge and PCK in mathematics teachers. However, little is known about what role content knowledge plays in developing PCK and how content knowledge is integrated into PCK. Additionally, few existing studies on the relationship between content knowledge and PCK were conducted with K-12 teachers. Given community college faculty's strong content knowledge and lack of pedagogical training, research on community college faculty PCK will contribute to a better understanding of the interactions between content knowledge and PCK. In this regard, this study aims to explicate how content knowledge is related to PCK in community college science faculty.

Purpose of Study

The primary purpose of this study was to describe the characteristics of PCK in community college biology instructors. Additionally, this study aimed to understand how content knowledge related to their PCK and to characterize contributing sources they used to develop their PCK.

Research Questions

Research questions that guided this study are as follows:

1. What are the characteristics of PCK in community college biology instructors?
2. How does content knowledge relate to PCK in community college biology instructors?
3. What sources do community college biology instructors use to develop PCK?

Rationale of Study

Since the President's Council of Advisors on Science and Technology (2012) reported most students who changed majors do so after participating in an introductory course of mathematics, science, or engineering, then community colleges have a great opportunity to provide students with positive STEM experiences in introductory courses that may encourage them to complete STEM-related degrees and pursue STEM-related careers. Prior research has shown PCK is a key component in shaping teacher practice and positively influencing student learning outcomes in primary and secondary (K-12) education (Ball et al., 2008; Baumert, et al., 2010; Buchmann, 1982, 1984; Cochran, 1997; Gess-Newsome, 2013; Gess-Newsome & Ledermann, 1995; Hill et al., 2005; Keller et al., 2017; Tobin & Garnett, 1988). However, most K-12 teachers have been formally trained in pedagogy with a secondary emphasis placed on acquiring the necessary content knowledge. In contrast, many post-secondary science faculty do not have any formal pedagogical training or education because they are only required to have post-baccalaureate degrees in the content area they are expected to teach. For example, community college faculty must have a master's level degree while science faculty at 4-year institutions must have a doctorate level degree in their content area. Hence, findings from research on K-12 teachers' PCK might not be able to be applied to post-secondary instructors because of the difference in educational training and preparation between post-secondary faculty and K-12 teachers. Since post-secondary science instructors are formally trained to be experts in their content knowledge without any pedagogical training, this study was important in that it clarified the relationship between content knowledge and PCK and identified sources used by community college biology faculty to develop their PCK.

Significance of Study

The significance of this study was twofold. First, from a theoretical point of view, this study addressed the theoretical deficiencies of post-secondary PCK research by characterizing community college biology instructors' PCK and the sources of their PCK development.

Additionally, this study clarified how content knowledge was related to PCK in order to fill a salient gap in the research on PCK. Second, from a practical point of view, this study provided significant insights about ways to support community college faculty in their PCK development that enables them to provide positive STEM experiences in the classroom, which in turn can improve student learning outcomes, increase completion rates in STEM courses, and encourage more students to pursue STEM degrees and STEM careers. Furthermore, this study can contribute to the improvement of science teaching in community college biology courses by addressing potential needs for professional development that encourages open dialogue among STEM faculty to discuss different ways to develop PCK such as sharing ideas about successful teaching strategies that improve student learning outcomes and increase course completion rates for biology. The results of this study can potentially be applied outside of STEM areas to address the professional development needs of all community college faculty, not just science faculty, and show the importance of professional development specifically designed to enhance PCK development for all community college faculty in order to improve student learning outcomes and increase completion rates for all courses and programs of study, regardless of discipline.

CHAPTER 2

LITERATURE REVIEW

In this chapter, a review of the research literature related to the three research questions is provided in detail. The three research questions are:

1. What are the characteristics of PCK in community college biology instructors?
2. How does content knowledge relate to PCK in community college biology instructors?
3. What sources do community college biology instructors use to develop PCK?

First, the importance of STEM education and the roles of community colleges in STEM education are presented followed by descriptions of general issues at community colleges and the roles of faculty in community colleges. Next, relevant research is presented about PCK as both a theoretical framework and an analytical framework. Finally, research regarding the characteristics of PCK and sources post-secondary instructors use to develop PCK as well as the relationship between content knowledge and PCK is presented.

The Importance of STEM Education

The President's Council of Advisors on Science and Technology (2012) recently reported that there were not enough graduates in the United States with post-secondary degrees in science, technology, engineering, and mathematics (STEM) fields of study. Additionally, many businesses and industries have indicated concerns that these insufficient numbers of STEM graduates with baccalaureate and associate level degrees will severely hinder the United States' global competitiveness in STEM areas (Malcolm & Feder, 2016).

While there continues to be a growing interest in STEM disciplines among high school graduates planning to attend a 2-year or 4-year institution (National Science Board, 2014; National Center for Education Statistics, 2013), 6-year completion rates for STEM degrees remain obviously lower at 40% compared to the 56% completion rates among all students who first enrolled in 2007 (President's Council of Advisors on Science and Technology, 2012; Shapiro, et al., 2013). Additionally, the majority of students who intended to pursue a STEM major did not earn a degree in these fields; also, most students changed their majors after participating in an introductory course of mathematics, science, or engineering (President's Council of Advisors on Science and Technology, 2012).

Early research studies indicated many students decided to switch to non-STEM majors even though they performed well in STEM-related introductory courses and were capable of earning STEM degrees (Brainard & Carlin, 1998; Seymour & Hewitt, 1997). More recently, Malcolm and Feder (2016) argued there was a combination of factors that supported students who completed STEM degrees, including the "students' individual decision making in response to factors in their institutions (e.g., quality of teaching, availability of support structures, discovery of attractive alternative majors) and external factors (e.g., early educational preparation, financial concerns, and larger social issues that affect specific groups)" (p. 32). It is important to understand why students interested in STEM degrees are leaving the STEM field.

The Role of Community Colleges in STEM Education

Typically, community colleges are cost-effective institutions that are accessible to everyone. They are two-year institutions that serve a diverse population of students. Commonly, community colleges offer many types of degree programs, including several educational pathways in STEM areas that target both high-skill and middle-skill jobs. The two notable types of programs related to STEM education are technical programs and transfer programs. The primary goal of technical programs is to prepare students with the skills and knowledge to enter STEM-related areas in the workforce. In contrast, transfer programs are designed to prepare students with the pre-requisite knowledge and skills in order to transfer to four-year institutions to complete a bachelor's degree or higher in STEM-related fields.

The National Center for Education Statistics (2014) reported two-year community college students accounted for 40 percent of all undergraduate enrollment in 2012. Additionally, at some point during their educational journey, about half of community college students in 2003-2004 were enrolled in a STEM-related field (Van Noy & Zeidenberg, 2014). The President's Council of Advisors on Science and Technology (2012) reported most STEM students changed their majors after they participated in an introductory course of mathematics, science, or engineering. Therefore, community colleges have great potential for providing positive experiences to a significant number of students in introductory STEM courses, which are transferrable to 4-year programs, and may encourage them to complete STEM-related degrees. Malcolm and Feder (2016) concluded community colleges have two important roles, including focusing on workforce needs as well as preparing transfer students who may potentially pursue advanced STEM degrees. However, despite its' important role in STEM education, Labov (2012) highlighted the severely limited focus of post-secondary STEM research in community colleges compared to its' four-year counterparts. This study contributes to the limited research base by exploring the pedagogical content knowledge of STEM faculty at community colleges and its' potential impact on students' success in course completion of STEM-related courses.

Issues in Community Colleges

According to the American Association of Community Colleges (2012), several current issues with community colleges have been identified, including undefined or outdated mission statements, low collaboration between community colleges, lack of community support, unproductive results, low completion rates, students' unpreparedness for the rigors of higher education, and the wide skills gap between students and workforce needs. In particular, low completion rates, student's unpreparedness, and the wide skills gap are the greatest concerns relevant to this study and are discussed in greater detail.

Low completion rates. The American Association of Community Colleges (2012) reported that less than half of all community college students have graduated or transferred to a 4-year institution within six years of initial enrollment. Among these students, Malcolm and Feder (2016) assessed that "about 20 percent of STEM community college students attained any STEM credential 6 years after enrollment" (p. 49). However, it should be noted that community college students have a variety of educational goals. They may choose to earn a 2-year associate's level degree, transfer to a 4-year institution (with or without earning the 2-year degree), earn a certificate or diploma, or learn job-related skills (Malcolm & Feder, 2016). Due to these various intentions, Van Noy and Zeidenberg (2014) insisted that multiple measures of community college STEM outcomes were necessary to assess the success of community college students' outcomes, not just a single focus on degree completion. Rassen et al. (2013) further asserted that these multiple measures should include degree/credential completion, degree/credential attainment at other institutions, continued enrollment, and employment. As the American Association of Community Colleges (2012) concluded, "If community colleges are to contribute powerfully to meeting the needs of 21st century students and the 21st century economy, education leaders must reimagine what these institutions are – and are capable of becoming" (p. vii).

Students' unpreparedness for higher education. The Harris Interactive Survey (2011) polled 1,205 community college students on various issues regarding school, including ease of getting necessary courses and the level of difficult of college-level coursework compared to high school classes. The survey found that 52% of all community college students felt unprepared for college-level coursework because their high schools did not place a higher emphasis on basic skills or incorporate a greater challenge into courses that were offered (Harris Interactive, 2011). The American Association of Community Colleges (2012) recommended that community colleges should reduce the number of students unprepared for college work by half by increasing the number of students who take developmental courses before taking freshman-level courses and accelerating these developmental courses so they do not hinder student completion rates.

Wide skills gap. The American Association of Community Colleges (2012) report also recommended that community colleges do a better job of preparing students for the workforce by focusing on career and technical education. Former President Obama referred to this problem in his 2012 State of the Union address in which he stated, “We shouldn’t settle for a country where a shrinking number of people do really well while a growing number of Americans barely get by.” He further elaborated that we need to promote “an economy where everyone gets a fair shot and everyone does their fair share, and everyone plays by the same set of rules.”   In this way, former President Obama recognized community colleges as one of the key players in designing worker training programs across the country, and called for many of these schools to ramp up their partnerships with area businesses to create “community career centers,” where residents could train for jobs currently available in their regions.

Given the potential of community colleges to expose a significant number of students to introductory STEM courses, the issues of low completion rates, students’ unpreparedness, and the wide skills gap should be addressed at both the instructional and administrative levels within the community college institution. This research study focuses on the instructional level by addressing the potential of community college faculty to provide positive STEM experiences in introductory courses that may inspire students to complete STEM-related degrees and pursue STEM-related careers.

Role of Faculty in Community Colleges

According to Rifkin (2017), community college faculty may be required to play multiple roles in the post-secondary educational setting, including instruction, research, institutional improvement, and community involvement. In particular, community college faculty place the greatest importance on their role as instructor which is most relevant to this study and is discussed in greater detail.

Instruction. A primary goal of community colleges is providing open-access education to everyone. Hence, anyone who wants to pursue additional education is accepted into the community college. According to Rifkin (2017), "this open-access mission places the responsibility of student success in the hands of the faculty." A student-centered approach to education is necessary in order for students with such a wide range of abilities, interests, and goals to be successful. Therefore, community college faculty spend 15 hours or more of their time teaching and a majority of the remaining time preparing for instructional time and working with students outside of the classroom. Rifkin (2017) asserted that "community college faculty register more student contact hours than any other educational sector."

Community college faculty face challenges with this combination of heavy teaching loads and academically-challenged student populations. Although they are dedicated to excellence in teaching, many community college faculty are only required to have a master's level degree in the content area they teach; many of them do not have any formal pedagogical training or education. This lack of pedagogical education can be seen in their selected modes of instruction and assessment. Rifkin (2017) found that in order "to contend with large numbers of students, community college faculty rely heavily on lecture and lecture-discussion as the dominant modes of instruction. [Additionally,] to contend with the less-than-college-level literacy skills of students, instructors use multiple-choice exams instead of essays or other forms of writing assessment." However, community colleges are promoting the use of technology as a way to reach more students and accommodate a number of different learning styles, but the research is still limited on how these instructional tools and technological practices affect student learning outcomes. Rifkin (2017) concluded, "The pedagogical demands of an open-access institution can be frustrating and require more attention as the community college student population becomes more varied. Maintaining faculty satisfaction and vitality while striving to meet societal demands for educational opportunity for all who can benefit will be a tough task, but the future of the community college as a corridor of educational opportunity depends on it."

Pedagogical Content Knowledge

Shulman (1986) first described pedagogical content knowledge (PCK) as knowledge "which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge *for teaching* … the particular form of content knowledge that embodies the aspects of content most germane to its teachability" (p. 9). He further clarified PCK as "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman, 1987, p. 8). In his initial discussions of PCK, Shulman (1986) described two primary dimensions that fall within the category of PCK including useful forms of representations and the recognition of student misconceptions with "the instructional conditions necessary to overcome and transform those [misconceptions]" (p. 10). Gudmundsdottir (1987a, 1987b) asserted that PCK is the form of knowledge that distinguishes science teachers from scientists. Additionally, Cochran (1997) argued that teachers and scientists do not differ in their content knowledge, but they do differ in how this knowledge is organized and utilized from either a teaching perspective to improve students' scientific understanding or a research perspective to develop new scientific knowledge.

Conceptualization of PCK. Many researchers have supported Shulman's (1986) concept that pedagogical content knowledge is the foremost component of teaching expertise (Carlsen, 1987; Cochran, 1997; Grossman, Wilson, & Shulman, 1989; Gudmundsdottir, 1987a; Gudmundsdottir, 1987b; Marks, 1990; Park & Oliver, 2008a) and have expanded his original model to incorporate more specific elements of PCK (Cochran, DeRuiter, & King, 1993; Fernandez-Balboa & Stiehl, 1995; Grossman, 1990; Magnusson, Krajcik, & Borko, 1999; Marks, 1990; Park & Oliver, 2008a; Tamir, 1988).

Many researchers have adopted Shulman's (1986) two original dimensions of PCK (useful forms of representations and the recognition of student misconceptions) as the basis to create expanded models of PCK, which are summarized in Table 2.1. Tamir (1988) expanded Shulman's (1986) original model by specifically differentiating between general pedagogy and subject matter specific pedagogy in relation to four categories, including student, curriculum, instruction, and evaluation, while simultaneously distinguishing between knowledge and skill. Grossman (1990) expanded Shulman's (1986) original model to include teachers' beliefs about the purposes for teaching specific subject matter and their knowledge of available curriculum materials. Marks' (1990) model of PCK also added two components to Shulman's (1986) original model, including knowledge of subject matter and knowledge of instructional media. Cochran, DeRuiter, and King (1993) developed the model of pedagogical content knowing (PCKg) to reflect the dynamic nature of knowledge development which includes teachers' understanding of their students' characteristics (i.e. abilities, learning strategies, ages, developmental levels, attitudes, motivations, prior knowledge) and teachers' understanding of the learning environments (i.e. social, political, cultural, physical) of their students. Fernandez-Balboa and Stiehl (1995) expanded Shulman's (1986) original model of PCK to incorporate five knowledge components of PCK, including subject matter, students, instructional strategies, teaching context, and teaching purposes. Magnusson et al. (1999) also expanded the original model of PCK to integrate five components specific to science teaching, including orientation to teaching science, knowledge of science curricula, knowledge of assessment of scientific literacy, knowledge of instructional strategies, and knowledge of students' understanding of science.

Table 2.1

Components of Different Conceptualizations of PCK

	Knowledge of:							
Scholars	Represent-atins & Strategies	Student Learning & Conceptions	Subject Matter	General Pedagogy	Subject Matter Specific Pedagogy	Curriculum & Media	Context	Purposes
Shulman (1986)	✓	✓	---	---	---	---	---	---
Tamir (1988)	✓	✓	✓	✓	✓	✓	---	---
Grossman (1990)	✓	✓	---	---	---	✓	---	✓
Marks (1990)	✓	✓	---	---	---	✓	---	---
Cochran et al. (1993)	✓	✓	✓	✓	---	---	✓	---
Fernandez-Balboa & Stiehl (1995)	✓	✓	✓	---	---	---	✓	✓
Magnusson et al. (1999)	✓	✓	✓	✓	✓	✓	---	✓

Note: This table was adapted from van Driel et al., 1998

The expanded models of PCK presented here are not meant to serve as an exhaustive list, but rather to establish that there is no current universally accepted conceptual model of PCK. While most scholars differed in the number, specific labels, and descriptions of the various components they integrated into their PCK models, they all incorporated Shulman's (1986) two original elements (knowledge of useful representations and knowledge of student misconceptions).

Analytical Framework of PCK. This research study employed the comprehensive working definition of PCK developed by Park and Oliver (2008a) as "*teachers' understanding and enactment* of how to help a group of students understand specific subject matter using multiple instructional strategies, representations, and assessments while working within the contextual, cultural, and social limitations in the learning environment" (p. 264). Figure 2.1 shows the Pentagon Model of PCK developed by Park and Chen (2012), which was adapted from Park and Oliver's (2008b) model. This model is used to conceptualize PCK in this study because it addresses the five components of PCK for science teaching identified in previous research by Tamir (1988), Grossman (1990), and Magnusson et al. (1999).

Based on Park and Oliver's original PCK model (2008b), Park and Chen (2012) identified the five components as: (a) Orientations toward Teaching Science (OTS), (b) Knowledge of Students' Understanding in Science (KSU), (c) Knowledge of Science Curriculum (KSC), (d) Knowledge of Instructional Strategies and Representations (KISR), and (e) Knowledge of Assessment of Science Learning (KAs)" (p. 925). Park and Oliver (2008a) described the first component of the pentagon model of PCK labeled *orientations to science teaching* "refers to teachers' beliefs about the purposes and goals for teaching science at different grade levels" (Park & Oliver, 2008a, p. 266). Park and Oliver (2008a) argued that this component influences the construction of PCK "that guides instructional decisions, the use of particular curricular materials and instructional strategies, and assessment of student learning" (p. 266).

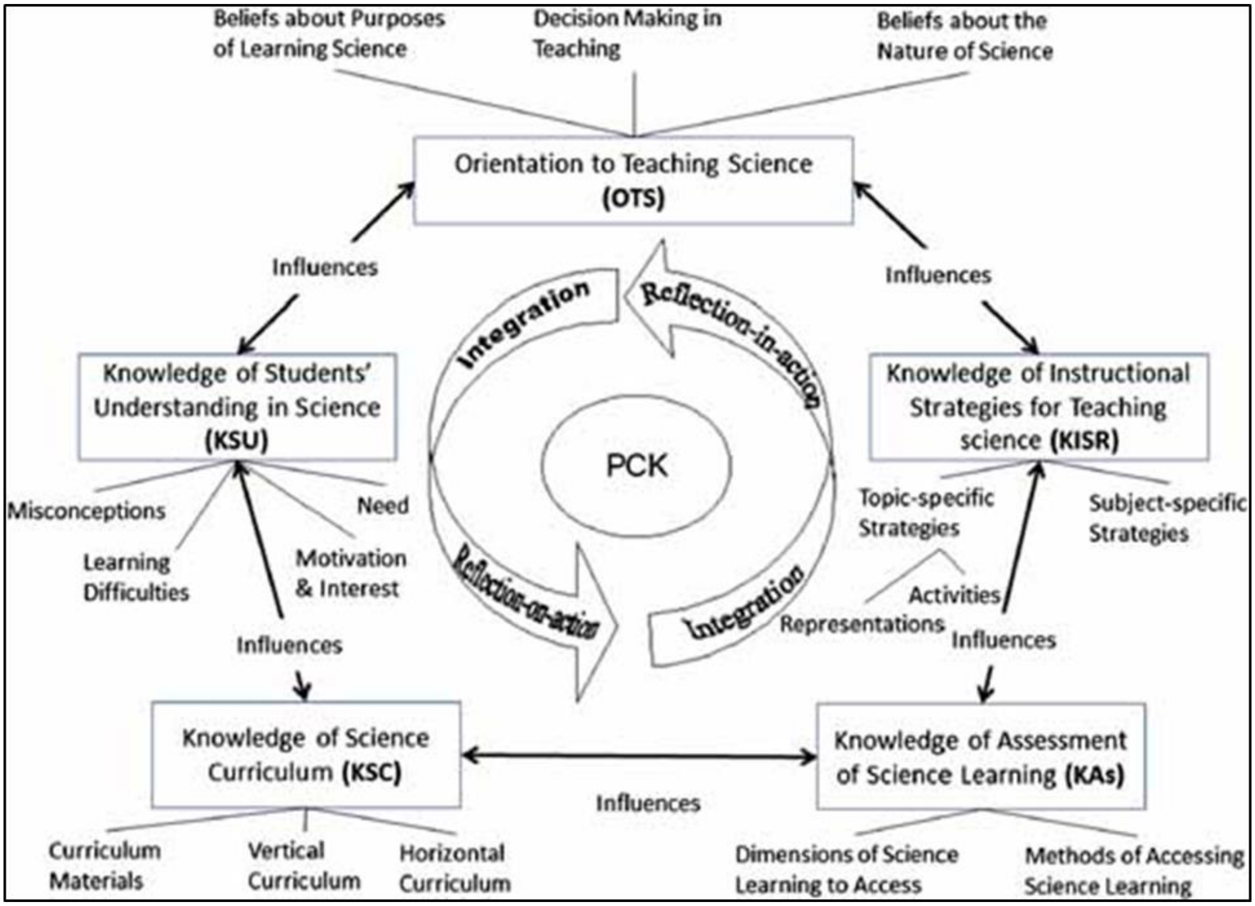

Figure 2.1. Pentagon Model of PCK for Science Teaching (Park & Chen, 2012)

The second component of this PCK model labeled *knowledge of students' understanding in science* argues that "teachers must have knowledge about what students know about a topic and areas of likely difficulty" if they want to use their PCK effectively (Park & Oliver, 2008a, p. 266). Next, the third component identified in this PCK model is *knowledge of science curriculum*, which "refers to teachers' knowledge about curriculum materials available for teaching particular subject matter" and "is indicative of teacher understanding of the importance of topics relative to the curriculum as a whole", including both horizontal and vertical curricula (Park & Oliver, 2008a, p. 266). The fourth component in this model, labeled *knowledge of instructional strategies and representations for teaching science*, consists of both subject-specific strategies and topic-specific strategies. Park and Oliver (2008a) described subject-specific strategies as "general approaches to instruction that are consistent with the goals of science teaching in teachers' minds such as learning cycles, conceptual change strategies, and inquiry-oriented instruction" (p. 266). They further elaborated that topic-specific strategies "refer to specific strategies that apply to teaching particular topics within a domain of science" (p. 266). Lastly, the fifth component of the pentagon model of PCK, labeled *knowledge of assessment of science learning*, is made up of "knowledge of the dimensions of science learning important to assess, and knowledge of the methods by which that learning can be assessed", such as various instruments and approaches for assessment (Park & Oliver, 2008a, p. 266).

PCK of College Science Instructors. Few research studies have described PCK of post-secondary science instructors (Dotger, 2011; Fernández-Balboa & Stiehl, 1995; Jang, 2011; Jang, Tsai, & Chen, 2013; Major & Palmer, 2006; Padilla, Ponce-de-León, Rembado, & Garritz, 2008). Of these, only two included biology faculty among their participants (Fernández-Balboa & Stiehl, 1995; Major & Palmer, 2006). Fernández-Balboa and Stiehl (1995) challenged the scholar versus teacher dichotomy in post-secondary education by describing five generic components of PCK that emerged from ten effective college instructors across multiple disciplines, including biology, business, education, kinesiology, music, nursing, special education, and speech communication. These five generic PCK components included the instructor's knowledge about "(a) the subject matter, (b) the students, (c) numerous instructional strategies, (d) the teaching context, and (e) one's teaching purposes" (p. 293). More recently, Major and Palmer (2006) discussed the development of PCK for thirty-one college faculty across multiple disciplines, including English, mathematics, biology, physics, nursing, business, pharmacy, and education, during a problem-based learning (PBL) project that focused on the implementation of PBL in their college classrooms. Major and Palmer (2006) found that this institutional initiative supported the transformation of PCK in each participant and the reported PCK development was cemented by providing opportunities to discuss their new knowledge of PBL.

The remaining studies that addressed PCK of post-secondary science instructors included research participants from science disciplines other than biology, such as earth science, physics, and chemistry. Dotger (2011) found the lesson study process useful in focusing the discussions of earth science graduate teaching assistants around learners rather than course logistics. Jang (2011) described how students perceived the changes in PCK of one college physics instructor over the course of one semester due to her participation in professional development. The results indicated that significant differences in students' perceptions were noted in only two of the four described PCK components, including subject matter knowledge and instructional representations and strategies. Similarly, Jang et al. (2013) compared students' perceptions of PCK between novice and experienced university physics instructors. They found the instructional representations and strategies category to be the only PCK component statistically different between the two instructors. Additionally, Padilla, et al. (2008) characterized the PCK of four university chemistry professors using Mortimer's Conceptual Profile model as an evaluation tool. In this study, the researchers described and categorized the PCK of these instructors into five conceptual profiles, including "perceptive/intuitive, empiricist, formalist, rationalist, and formal rationalist" (p. 1389).

It is important to note that among the small number of research studies describing PCK of post-secondary science instructors, only two included biology faculty among their research participants, and these studies focused on instructors at four-year institutions. This research study aims to address the lack of PCK research specific to post-secondary biology instructors at two-year institutions by describing the PCK characteristics of biology instructors at the community college level.

Development of PCK. Many research studies have described the relationship between teacher PCK and teaching experience, professional development, mentorship, and content knowledge (CK) at the K-12 level of education (Appleton, 2008; Burton, 2013; Clermont, Borko, & Krajcik, 1994; Cochran et al., 1993; Dotger, 2011; Hanuscin, Menon, Lee, & Cite, 2011; Jang, 2011; Jang et al., 2013; Kanter & Konstantopoulos, 2010; Khourey-Bowers & Fenk, 2009; Lederman, Gess-Newsome, & Latz, 1994; Major & Palmer, 2006; McNeill & Knight, 2013; Peers, Diezmann, & Watters, 2003; See, 2014; van Driel & Berry, 2012; van Driel, de Jong, & Verloop, 2002; van Driel, Verloop, & de Vos, 1998). Additionally, there are several research studies that focused on PCK development at the post-secondary level of education in a science discipline (Dotger, 2011; Jang, 2011; Jang et al., 2013; Major & Palmer, 2006). However, there is only one study researching the development of PCK specifically in biology instructors at the post-secondary level of education (Major & Palmer, 2006). It is important to note that these few research studies of PCK development at the post-secondary level of education solely focused on science instructors at four-year institutions, and only one of these studies included biology instructors among the participants. There are no studies that examined the PCK development of two-year community college science instructors. This research study aims to contribute to the post-secondary research literature of PCK development and address the disparity in PCK research between four-year and two-year post-secondary science instructors by characterizing PCK and identifying sources of PCK development in community college biology instructors.

Teaching Experience. Multiple research studies have positively correlated years of teaching experience with PCK development (Cochran et al., 1993; Lederman et al., 1994; van Driel et al. 1998; van Driel et al., 2002). Cochran et al. (1993) argued "beginning teachers continue to develop toward more integrated [PCK] with experience" (p. 270), and Lederman et al. (1994) asserted that most pre-service science teachers and novice science teachers demonstrated little to no PCK. Both of these studies supported later assertions by van Driel et al. (1998) and van Driel et al. (2002) that years of teaching experience significantly impacts the development of PCK specifically in K-12 science teachers. van Driel et al. (1998) found that adequate subject matter knowledge appeared to be a necessary prerequisite in order for teaching experience to significantly impact the PCK of K-12 science teachers. Additionally, van Driel et al. (2002) concluded that PCK development was shaped primarily by teaching experience in twelve secondary pre-service chemistry teachers.

It is important to note that research regarding the correlation between PCK development and teaching experience has been vigorously studied at the K-12 education level across many disciplines (Cochran et al., 1993; Lederman et al., 1994), including science (van Driel et al. 1998; van Driel et al., 2002). However, there are almost no research studies in post-secondary science disciplines that have investigated this particular correlation between teaching experience and development of PCK. Jang et al. (2013) compared students' perceptions of PCK between novice and experienced physics instructors at one four-year institution. They found the instructional representations and strategies category to be the only PCK component statistically different between the two instructors with the experienced instructor using more instructional representations of the physics content compared to the novice instructor. These findings suggested teaching experience also positively influences PCK development in post-secondary science instructors.

Professional Development. van Driel and Berry (2012) asserted that professional development programs designed to develop teacher PCK "should be closely aligned to teachers' professional practice and, in addition to providing teachers with specific input, should include opportunities to enact certain instructional strategies and to reflect, individually and collectively, on their experiences" (p. 26). They argued that professional development programs should be designed "based on constructivist and situative theories rather than on behavioral approaches" (p. 27). They concluded that "professional development programs aimed at the development of teachers' PCK should be organized in ways that closely align to teachers' professional practice, including opportunities to enact certain (innovative) instructional strategies and materials and to reflect, individually and collectively, on their experiences" (p. 27). Khourey-Bowers and Fenk (2009) used constructivist professional development activities to enhance the content knowledge, PCK, and self-efficacy of sixty-nine K-12 teachers regarding chemistry topics. They further asserted that this type of professional development should include "instruction [that] connect[s] representational models with alternative conceptions, integrating radical and social constructivism" (p. 437). Additionally, Kanter and Konstantopoulos (2010) reported that professional development for the use of problem-based science curricula increased PCK of urban K-12 science teachers. They described a correlation between teacher PCK and increased student achievement in science with the implementation of problem-based curriculum. More recently, McNeill and Knight (2013) found a positive correlation between the use of professional development workshops and development of PCK for scientific argumentation in seventy K-12 teachers, including elementary, middle- and high-school teachers. Burton (2013) reported significant improvement of teacher PCK about nature of science (NOS) in seventeen secondary science teachers that participated in professional development activities for NOS.

Additionally, several research studies have investigated a positive correlation between PCK development and professional development in post-secondary science instructors (Dotger, 2011; Jang, 2011; Major & Palmer, 2006). In 2006, Major and Palmer found that an institutional PBL initiative positively influenced the development of PCK in the thirty-one participants who represented post-secondary faculty from multiple disciplines, including English, mathematics, biology, physics, nursing, business, pharmacy, and education. Additionally, they reported the newly transformed PCK was cemented in these post-secondary instructors by providing additional opportunities to discuss their new knowledge of PBL during professional development programs (Major & Palmer, 2006). More recently, Dotger's (2011) smaller study of four earth science graduate teaching assistants reported professional development about the lesson study process was useful in focusing the participants' discussions around learners, thus demonstrating positive PCK development. Finally, Jang's (2011) case study of one post-secondary physics instructor found that "organized workshops helped the case teacher to better understand students' prior conceptions of the subject matter and learning difficulties, and further facilitated her adjustment of instructional strategies" (p. 663).

Again, it is important to highlight that research regarding the correlation between professional development and PCK development has primarily focused on the K-12 education level across many disciplines (Burton, 2013; Kanter & Konstantopoulos, 2010; Khourey-Bowers & Fenk, 2009; McNeill & Knight, 2013; van Driel & Berry, 2012). However, there are fewer studies that reported similar findings in post-secondary science instructors (Dotger, 2011; Jang, 2011; Major & Palmer, 2006), which focused on four-year institutions. This study aims to address this deficiency in the post-secondary PCK development research literature by identifying sources of PCK in two-year community college biology instructors, which may include specific professional development opportunities.

Mentorship. Several research studies showed the significant impact of mentorship on PCK in K-12 science teachers (Appleton, 2008; Clermont et al., 1994; Hanuscin et al., 2011; Peers et al., 2003; See, 2014; van Driel et al., 2002). Clermont et al. (1994) found that experienced secondary chemistry teachers have a greater range of instructional representations and adaptations for teaching fundamental chemistry concepts compared to novices. Based on these findings, they concluded that "highly experienced science teachers (with high pedagogical content knowledge in a given subject area and grade level) mentor beginning science teachers whose [PCK] may not be as well developed" (p. 438). Van Driel et al.'s (2002) study of twelve secondary pre-service chemistry teachers found mentors positively influenced PCK development in some, but not all, of their participants. Additionally, Appleton's (2008) findings supported the conclusions of Peers et al. (2003) that mentoring can be critical in helping science teachers make lasting changes in their instructional practice. Furthermore, Hanuscin et al. (2011) concluded that mentoring was an effective way for supporting the PCK development of prospective teacher-educators. They also argued that mentored internships bridge the gap between what is learned in a teacher-education course and what is put into actual practice (Hanuscin et al., 2011). Most recently, See (2014) found that mentoring of novice K-12 teachers by experienced teachers in the same school significantly impacted the PCK development of the novice teachers in three areas including subject matter knowledge, general pedagogical knowledge, and knowledge of context.

It is important to note that all of the research regarding the correlation between mentorship and PCK development focused on K-12 teachers. There were no research studies found which investigated the effects of mentorship on PCK development in post-secondary science instructors.

Sources of PCK Development in Science Instructors. Many research studies have identified various sources used to develop PCK in science instructors, including teaching experience, knowledge of students' understanding, subject matter knowledge, professional development programs, observation of classes, pedagogical knowledge, previous PCK instruction, mentorship, reflection, and contact with cooperating teachers. Table 2.2 summarizes the various sources of PCK development for science instructors described in the research literature for both K-12 and post-secondary levels of education. Table 2.2 also clearly shows that the majority of these research studies focused on primary and secondary science teachers, while very few studies investigated the sources of PCK development in post-secondary science instructors. Furthermore, all of the post-secondary research studies investigated PCK development in four-year science faculty. This study aims to address the insufficient research in PCK development of post-secondary science instructors by identifying sources used by two-year community college biology instructors to develop their PCK.

Table 2.2

Sources of PCK Development for Science Instructors

Sources	K-12 Science Research Scholars	Post-Secondary Science Research Scholars
Teaching Experience	Barnett & Hodson (2001); Cochran et al. (1993); Goodnough & Hung (2009); Grossman (1990); Kanter & Konstantopoulos (2010); Khourey-Bowers & Fenk (2009); Lederman et al. (1994); McNeill & Knight (2013); Shulman (1987); van Driel et al. (1998); van Driel et al. (2002)	Jang et al. (2013)
Knowledge of Students' Understanding	Clermont et al. (1994); Geddis (1993); Lederman et al. (1994); van Driel et al. (1998)	Not found
Subject Matter Knowledge	Cochran & Jones (1998); Grossman (1990); Kanter & Konstantopoulos (2010); Luft, et al. (2011); Marks (1990); Park & Oliver (2008a, 2008b); Sanders, Borko, & Lockard (1993); Shulman (1987); Smith & Neale (1989); van Driel et al. (1998)	Not found
Professional Development	Barnett & Hodson (2001); Bertram & Loughran (2012); Burton (2013); Clermont et al. (1993); Clermont et al. (1994); Goodnough & Hung (2009); Grossman (1990); Kanter & Konstantopoulos (2010); Khourey-Bowers & Fenk (2009); Luft, et al. (2011); McNeill & Knight (2013); Park & Oliver (2008a, 2008b); Rozenszajn & Yarden (2014); van Driel & Berry (2012); van Driel et al. (2002)	Dotger (2011); Jang (2011); Jang et al. (2013); Major & Palmer (2006)
Observation of Classes	Grossman (1990)	Not found
Pedagogical Knowledge	Marks (1990); Sanders et al. (1993)	Not found
Previous PCK Construction	Marks (1990)	Not found
Mentors	Appleton, 2008; Clermont et al. (1994); Hanuscin, et al. (2011); Peers et al. (2003); See (2014); van Driel et al. (2002)	Not found
Reflection	Burton (2013); Goodnough & Hung (2009); Park & Oliver (2008a, 2008b)	Goodnough (2006); Jang (2011)
Contact with Cooperating Teachers	Kanter & Konstantopoulos (2010); Khourey-Bowers & Fenk (2009); Luft, et al. (2011); McNeill & Knight (2013)	Jang (2011)

In previous sections of the literature review, research was presented which described the relationship between teacher PCK and teaching experience, professional development, and mentorship. In the next section, research literature is presented describing the relationship between subject matter knowledge (content knowledge) and PCK. Therefore, in this section, a review of research literature related to additional PCK sources in science instructors is presented, including the roles of knowledge of students' understanding, observation of classes, pedagogical knowledge, previous PCK construction, reflection, and contact with cooperating teachers in PCK development.

Additional Sources of PCK. Several studies positively correlated teacher's knowledge of students' understanding with increased PCK (Clermont et al., 1994; Geddis, 1993; Lederman et al., 1994; van Driel et al., 1998). For example, Clermont et al. (1994) found that experienced secondary chemistry teachers showed better use of more instructional strategies for teaching fundamental chemistry concepts compared to novices. Based on these findings, they concluded that teacher preparation programs should provide opportunities for pre-service science teachers to practice identifying student misunderstandings and adjusting their instructional strategies to accommodate their learners' various abilities. Additionally, Marks (1990) and Sanders et al. (1993) associated the improvements of pedagogical knowledge in K-12 science teachers with PCK development. Similarly, Marks (1990) also found teachers' previous construction of PCK was positively linked with permanent PCK development. It is important to note that the studies referenced here focused solely on K-12 science instructors, while there were no studies identified in the current literature identifying similar correlations in post-secondary science instructors.

Grossman (1990) associated PCK development in pre-service science teachers with opportunities to observe the science classes of other K-12 science teachers presenting similar topics. Additionally, research studies by Kanter and Konstantoploulos (2010), Khourey-Bowers and Fenk (2009), Luft et al. (2011), and McNeill and Knight (2013), argued that K-12 science teachers who cooperated together in group discussions of instructional design and delivery methods were better able to develop their PCK in a permanent way. Jang (2011) found a similar result in a case study of one post-secondary physics instructor. Furthermore, studies by Geddis (1993), Park and Oliver (2008b), Goodnough and Hung (2009), and Burton (2013), concluded that K-12 science teachers need time to reflect on their classroom experiences in order to positively affect their PCK development. Both Goodnough (2006) and Jang (2011) found similar results in post-secondary science instructors at four-year colleges.

Again, it is important to note the significant disparity in the literature between K-12 science teachers and post-secondary science instructors regarding various sources of PCK development (see Table 2.2). Also, it is important to emphasize that these few post-secondary research studies focused solely on four-year science faculty. This study aims to address the insufficient research regarding sources of PCK development in post-secondary science instructors by identifying sources used by two-year community college biology instructors to develop their PCK.

Relationship Between Content Knowledge (CK) and PCK. Since Shulman (1986) first described PCK, research efforts have focused on the positive correlation between teacher PCK and improved student learning outcomes in STEM areas at the K-12 education level (Ball, Thames, & Phelps, 2008; Baumert et al., 2010; Gess-Newsome, 2013; Gess-Newsome & Ledermann, 1995; Hill, Rowan, & Ball, 2005; Keller et al., 2017). Research findings by Ball et al. (2008), Baumert et al. (2010), and Hill et al. (2005) indicated positive effects of teacher PCK on student learning and achievement in secondary mathematics courses. Keller et al.'s (2016) research of seventy-seven secondary physics teachers in Germany and Switzerland found that teacher PCK positively predicted students' achievement. Finally, multiple research studies by lead researcher Gess-Newsome (2013) have repeatedly shown the correlation of teacher PCK on increased student achievement in secondary biology courses.

Additional studies have positively correlated subject matter knowledge (content knowledge) with PCK development in K-12 science teachers (Cochran & Jones, 1998; Grossman, 1990; Kanter & Konstantopoulos, 2010; Luft, et al., 2011; Marks, 1990; Park & Oliver, 2008a, 2008b; Sanders et al., 1993; Smith & Neale, 1989; Shulman, 1987; van Driel et al., 1998). Shulman (1987) first described PCK as the combination of content knowledge and pedagogy that informs the instructional decisions of teachers, regardless of discipline. Earlier research studies by Smith and Neale (1989), Grossman (1990), Marks (1990), Sanders et al. (1993), Cochran & Jones (1998), and van Driel et al. (1998) concluded that increased content knowledge positively correlated with the development of more sophisticated PCK in K-12 science teachers. Later research studies by Park and Oliver (2008a, 2008b), Kanter and Konstantopoulos (2010), and Luft et al. (2011) continued to support these earlier findings in K-12 science teachers. Friedrichson et al. (2009) found content knowledge is pre-requisite for PCK development in secondary biology teachers. However, Lee, Brown, Luft, and Roehrig (2007) argued that strong content knowledge does not necessarily lead to PCK development.

Furthermore, many research studies have shown the important roles of both teachers' content knowledge and pedagogical knowledge in designing good science instruction that positively impacts student understanding (Buchmann, 1982, 1984; Cochran, 1997; Gess-Newsome, 2013; Gess-Newsome & Ledermann, 1995; Keller et al., 2017; Tobin & Garnett, 1988). Loughran and Northfield (1996) initially asserted that many teachers are aware of the ongoing discrepancies between “their intentions for teaching and the practice that evolves as a consequence of the dailiness of teaching” (as cited by Loughran, Berry, & Mulhall, 2012, p. 1). Loughran et al. (2012) further contended,

> Approaches to professional learning that might encourage teachers to more readily respond to the inherent contradictions between intentions and actions in teaching are not necessarily supported at either a school or systemic level. Therefore, for those who choose to respond, the professional learning journey is often characterised by individual teachers finding themselves questioning their own practice and seeking new ways of constructing teaching and learning experiences without necessarily being supported, encouraged, or rewarded for so doing (p. 1).

Hoban (2002) and Berry and Milroy (2002) both reported that they recognized teaching is much more than just having a toolbox of great activities. Loughran et al. (2012) described “an expert pedagogue [as] one who chooses to use a particular teaching procedure at a particular time for a particular reason, because, through experience, that teacher has come to know how teaching in that way enhances student learning of the concept(s) under consideration” (p. 2). They further asserted, “Such pedagogical reasoning is important because it is the thinking central to creating a path through complex teaching and learning situations. It is a window into the thoughtful and skillful act of practice that is responsive to the given context, i.e. there is not the assumption that the same thing works the same way all of the time. The ability to adapt, adjust and make appropriate professional judgments, then, is crucial to shaping the manner in which teachers teach and respond to their students’ learning” (Loughran, et. al., 2012, p. 2).

It is important to note that all research describing the relationship between content knowledge and PCK focused solely on K-12 teachers. There are no studies that investigated this relationship between PCK and content knowledge in post-secondary science faculty. This study aims to address the lack of post-secondary research in this area by investigating the relationship between content knowledge and PCK in two-year community college biology instructors.

Summary

While many research studies have shown that PCK is a key component in shaping teacher practice and positively influencing student learning outcomes in primary and secondary (K-12) education (Ball et al., 2008; Baumert et al., 2010; Gess-Newsome, 2013; Gess-Newsome & Ledermann, 1995; Hill et al., 2005; Keller et al., 2017), it is important to note that most K-12 teachers have been formally trained in pedagogy with a secondary emphasis placed on acquiring the necessary content knowledge. In contrast, community college faculty are required to have a master's level degree in the content area they teach, and most science faculty at four-year institutions are expected to have a doctorate level degree in the content area they teach. Many post-secondary science faculty do not have any formal pedagogical training or education. Hence, PCK results from K-12 research cannot be directly applied to post-secondary PCK research because of this significant difference in teacher education, preparation, and training between K-12 teachers and post-secondary science faculty.

Additionally, it is important to note that the limited number of post-secondary PCK research studies for science faculty focuses on four-year institutions and rarely includes biology instructors as participants. Therefore, it is important to understand the characteristics of PCK, the relationship between content knowledge and PCK, and the sources being used to develop PCK in these post-secondary biology faculty, especially at the two-year community college level.

CHAPTER 3

METHODOLOGY

The purposes of this qualitative study are: 1) to describe the characteristics of PCK demonstrated by community college biology instructors; 2) to understand how content knowledge is related to PCK in community college biology instructors; and, 3) to characterize contributing sources to the development of PCK in community college biology instructors. The following research questions will be examined to achieve these purposes:

1. What are the characteristics of PCK in community college biology instructors?
2. How does content knowledge relate to PCK in community college biology instructors?
3. What sources do community college biology instructors use to develop PCK?

In this chapter, methodological approaches to answer the research questions are discussed in detail. First, a reflection of the researcher's epistemological and ontological views in relation to the study are described. Next, a general overview of the research design in this study is presented followed by a description of each of the components specific to this investigation, including research context, participants, data collection methods, data analysis methods, and trustworthiness of the study. Finally, the researcher's subjectivity statement is presented.

Epistemological and Ontological Views of the Researcher

Epistemology is the study of the origins and nature of knowing (Assalahi, 2015; Bryman, 1992; Crotty, 1998; Mack, 2010; Maykut & Morehouse, 1994). Specifically, epistemology focuses on "the construction of knowledge and the relationship between the knower and the known" (Assalahi, 2015, p. 313; Maykut & Morehouse, 1994). Ontology is the study of being and the nature of reality (Assalahi, 2015; Cohen, Manion, & Morrison, 2000; Crotty, 1998; Grix, 2004; Mack, 2010). Grix (2004) used Blaikie's definition of ontology as the study of "claims and assumptions that are made about the nature of social reality, claims about what exists, what it looks like, what units make it up and how these units interact with each other" (p. 59). Mack (2010) simplified this definition of ontology as the study of "what we mean when we say something exists" (p. 5). In this study, the researcher employed the epistemological stance of social constructivism and the ontological paradigm of interpretivism.

Social Constructivism. Social constructivist theory emphasizes the importance of culture, context, and language within society to learners in order to clarify their understanding and incorporate new knowledge (Derry, 1999; Kim, 2001; McMahon, 1997). Vygotsky (1978) argued that it was impossible to separate learning from its social context. According to Vygotsky (1978), "every function in the child's cultural development appears twice: first, on the social level and, later on, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relationships between individuals" (p. 57). Yilmaz (2008) summarized the basic assumptions and principles of the social constructivist learning theory for learning and knowledge. He described learning as an active and adaptive process that is situated within the context in which it occurs. Furthermore, he described knowledge as being socially constructed by the learner, thereby making it personal and idiosyncratic to the learner. Yilmaz (2008) reasoned that experience, prior understanding, and social interaction all play an interactive role together in the learning process. Yilmaz (2008) concluded that "effective learning requires meaningful, open-ended, challenging problems for the learner to solve" (p. 168).

Instructional models based on the theory of social constructivism emphasize the importance of collaboration among learners as well as between the learner and the teacher (Kim, 2001). Within the science classroom, these instructional models can include reciprocal teaching, peer collaboration, cognitive apprenticeships, problem-based instruction, webquests, anchored instruction and other methods that involve learning with others (Kim, 2001). For example, Slavin (2000) elaborated that two of Vygotsky's (1978) premises are most important to cooperative learning models, including the social nature of learning and the zone of proximal development.

von Glasserfeld (1995) stated that "knowledge does not and cannot have the purpose of producing an independent reality, but instead . . . has an adaptive function" (p. 3). Wasson (1996) reasoned that social constructivism is descriptive and, therefore, does not have a prescribed set of rules for designing a learning environment. Fosnot (1996) suggested that five general constructivist principles of learning can be applied to educational practices. First, she advocated that "learning is development" so teachers should provide opportunities for students to investigate their own questions. Next, Fosnot (1996) indicated that "disequilibrium facilitates learning" so teachers should encourage open-ended investigations that will highlight contradictions in students' understanding that can be further discussed to correct misconceptions. Thirdly, she surmised that "reflective abstraction is the driving force of learning" so students should be given opportunities to use reflective journaling as a means to make connections across their experiences in order to develop more sophisticated abstract thinking strategies. Subsequently, Fosnot (1996) suggested that "dialogue within a community engenders further thinking" so teachers should design their classrooms to encourage and support students in a community of discourse in which learners must effectively communicate and justify their ideas to their peers. Finally, Fosnot (1996) described learning as a process that "proceeds toward developing structures" so teachers should develop ways to challenge students' understandings in such ways that promote learners' development of more centrally-organized ideas which can be "generalized across experiences" (p.30).

Fosnot's (1996) five general constructivist principles are appropriate guidelines to use in the design of student-centered, productive learning environments in community college science classrooms because students are always constructing science knowledge within the social settings of classrooms and laboratories. Additionally, these principles can help shape biology faculty PCK by guiding the development and delivery of science curriculum in ways that increase student learning through challenging students' understandings with reflective discourse and thereby improving student learning outcomes.

In this study, the researcher's social constructivist views guided the development of the methodology used to investigate the three research questions. Since the researcher believes the social interactions between teachers and learners are the driving force to create new knowledge, the researcher selected a basic qualitative approach to this investigation, instead of a quantitative or mixed methods approach. A basic qualitative approach allowed the researcher to observe the interactions between teachers and students in the social context of a science classroom or laboratory setting as well as interview participants about their thoughts and ideas that influence their instructional decisions and assessment strategies in order to create a well-characterized picture of their PCK.

Interpretivism. Mack (2010) refers to the ontological paradigm of interpretivism "as constructivism because it emphasizes the ability of the individual to construct meaning" (p. 7). The interpretivist paradigm integrates hermeneutics and phenomenology (Mack, 2010). Ernest (1994) defines hermeneutics as the study of meaning and interpretation in historical texts by a cyclical process of meaning-making. Phenomenology considers "human beings' subjective interpretations, their perceptions of the world (their life-worlds) as our starting point in understanding social phenomena" (Ernest, 1994, p. 25). Mack (2010) concludes that "the ontological assumptions of interpretivism are that social reality is seen by multiple people and these multiple people interpret events differently leaving multiple perspectives of an incident" (p. 8).

This research study employed the interpretivist paradigm because research in a social setting, such as a classroom, can "never be [fully] objectively observed from the outside rather it must be observed from the inside through the direct experience of the people" (Mack, 2010, p. 8). Additionally, as Mack (2010) argued, the "uniform causal links that can be established in the study of natural science cannot be made in the world of the classroom where teachers and learners construct meaning" (p. 8). Newman and Benz (1998) stated that for interpretivist researchers, reality is "a social construct that embraces multiple interpretations" (p. 2). Cohen, Manion, and Morrison (2007) further clarifies that the role of the researcher in the interpretivist paradigm is to "understand, explain, and demystify social reality through the eyes of different participants" (p. 19).

There are several important ontological and epistemological assumptions associated with the interpretivist paradigm. Mack (2010) identified five ontological assumptions, including construction of reality is subjective; individuals interpret their own meanings of events; events cannot be generalized; there will always be multiple perspectives of one event; and, causation of events is determined through interpreted meanings (p.8). Mack (2010) also identified four epistemological assumptions related to the interpretivist paradigm. She concluded that knowledge is gained subjectively, inductively, situationally, and through personal experiences (p. 8).

There are several criticisms of the interpretivist paradigm. One criticism addresses the lack of "scientific procedures of verification" so that the "results cannot be generalized to other situations" (Mack, 2010, p. 8). However, this research study is designed to characterize PCK, clarify the relationship between content knowledge and PCK, and understand the sources used to develop PCK in community college biology instructors. Therefore, this study is primarily trying to expand on local theories for practice rather than generalize the findings.

Another criticism of the interpretivist paradigm involves the ontological assumption of subjectivity instead of objectivity (Mack, 2010). However, the researcher in this study would argue that all researchers are subjectively orienting themselves towards one particular method of research when they select a research paradigm, and all researchers bring with them their biases, beliefs, and subjective ideas regarding their research. By recognizing and acknowledging their own subjectivity, researchers can take a more objective stance when analyzing the data collected in their study.

Lastly, the interpretivist paradigm has been criticized for not acknowledging the political and ideological influences on knowledge construction and social reality (Mack, 2010). Positivist researchers seek to *explain* social phenomena using quantitative methods, while interpretivist researchers seek to *understand* social phenomena using qualitative methods. The researcher in this study would argue that it is most important to first *understand* the social phenomena before trying to change or to challenge it as critical researchers seek to do. In this study, the researcher specifically described strategies used to address potential issues of subjectivity, such as credibility, transferability, dependability, and confirmability, in the Data Analysis subsection Trustworthiness of Study.

Research Design

According to Merriam (2002), basic qualitative research "is designed to uncover or discover the meanings people have constructed about a particular phenomenon" (p. 19). Merriam (2002) also emphasized that "the researcher wants to obtain an in-depth understanding of a phenomenon, an individual, or a situation" (p. 19). Additionally, Bogdan and Biklen (2007) asserted that qualitative researchers "seek to grasp the processes by which people construct meaning" (p. 43). Patton (2015) described generic qualitative inquiry as a research design that uses qualitative methods such as interviewing, fieldwork observations, and document analysis, to answer straightforward questions without framing the inquiry within an explicit theoretical, philosophical, epistemological, or ontological tradition. Therefore, a generic qualitative approach was selected for this research study in order to characterize PCK, understand how content knowledge is related to PCK, and describe sources used to develop PCK in community college biology instructors while simultaneously listening to the stories and experiences of these teachers in community college biology courses.

Research Context

For this study, the researcher selected one southeastern community college as the research site where the researcher was employed as a faculty member, reducing the time needed for gaining access to the site and facilitating entry into the field. Convenience and the characteristics of this particular community college made this site suitable for answering the research questions. According to its website, the mission of this community college is to "educate, inspire, and support a diverse community of learners to achieve professional and personal success". Additionally, the website for this institution asserts that it "offers more than 40 curriculum programs, in which students work toward certificates, diplomas and degrees. Area residents and businesses can also take advantage of a variety of Continuing Education opportunities, as well as the High School Equivalency and Adult High School Diploma programs. High school students can also get a step ahead by starting their college education early". According to the National Center for Education Statistics (2015), this community college has a student enrollment of about 3300 with a student to faculty ratio of approximately 13:1. The student population is about 34% male and 64% female, and 65% of the students are age 24 and under. The racial/ethnicity demographics of the student population are as follows: 51% white; 33% African-American; 7% Hispanic or Latino; 1% Asian; 1% American Indian; 7% other (NCES, 2015). In 2015, the college employed 131 fulltime instructional faculty and 301 part-time instructional faculty (NCES, 2015). Currently, there are eleven science faculty including six males and five females.

Participants. In this study, participants were Biology faculty from one southeastern community college employed during the 2017 calendar year (Spring, Summer, and Fall). Selection criteria included Biology faculty who were currently teaching biology courses, and who agreed to complete all video recordings and interviews administered during the study. A total of four instructors participated in the research study. Table 3.1 provides an overview of participant characteristics, including their gender, the highest level of education attained, the number of years teaching at various levels of education, and the subject matter taught.

Table 3.1

Characteristics of Study Participants

Participant Name (pseudonym)	Gender & Ethnicity	Highest level of Education	Years of Teaching*	Subjects taught
David	Male Caucasian	Ph.D Cell Biology; Graduate Certificate in Exercise Physiology	CC 20 years	General Biology, Introduction to Anatomy & Physiology/Microbiology, Nutrition, Microbiology, Environmental Biology
Jerry	Male Iranian-American	Ph.D. Biomedical Sciences	CC 5 years	Chemistry, General Biology, Environmental Biology
Sheila	Female Caucasian	MS Health Administration; Graduate Certificates in Nutrition, Anatomy & Physiology	CC 8 years	Human Anatomy & Physiology (I, II), Nutrition, Health & P.E.
			9th grade 18 months	Health & P.E.
Vera	Female Caucasian	MS Zoology	CC 2 years	Human Anatomy & Physiology (I, II), Pathophysiology, General Biology, Environmental Biology
			Graduate School 4 years	General Biology Labs, General Zoology Labs, Vertebrate Zoology Labs

**Note:* CC stands for community college

IRB Approval and Recruitment of Participants

The researcher developed a research study proposal, including the consent form, interview protocols, and protocols for the collection of video recordings, and submitted it to the university's Institutional Review Board (IRB) for review and approval. Approval of this research study was received on May 18, 2017.

Subsequent to IRB approval, participants were recruited into the research study. The researcher approached the participants through in-person discussions at the research site. Initial contact with potential participants included an explanation of study criteria and informed consent forms (Appendix A). Informed consent was reviewed and obtained from each participant prior to data collection.

Data Collection

The researcher, who was also a community college biology instructor, discussed participation in the study and selection criteria with potential participants individually during available work hours at the research site. The researcher reiterated selection criteria, as well as participant protections, by providing the consent form prior to any data collection for the study.

First, the researcher completed preliminary background interviews designed to elicit information about participants' educational and professional backgrounds as well as their ideas about science teaching and learning. Next, the researcher video recorded three to six hours of traditional lecture, lab, and/or review sessions for two different topics selected by the participants for analysis. All participants had experience teaching in various instructional modalities, including traditional face-to-face settings, as well as hybrid and online settings. The researcher asked all participants to select content topics they would be presenting in a traditional classroom setting in order to minimize potential bias due to different settings. Participants were asked to choose one topic in which they felt strongly confident about their content knowledge and in teaching this subject matter. Participants were also asked to choose a second topic in which they felt less confident in teaching because they were less comfortable in their content knowledge. It is important to note that participants selected their strong and weak content topics based on their own perceptions of their understandings of the content, not based on specific measurements of content knowledge for the self-selected topics. Since all participants selected different topics, which may or may not have included a laboratory session, the researcher decided to focus the final data analysis only on the lecture for selected content topics. Table 3.2 summarizes the strong and weak content topics, as well as the courses for each topic, selected by each participant. David's strong content topic was genetics, while his weak content topic was plant evolution; both of these topics were observed in the same section of General Biology course for non-majors in the same semester. Jerry selected chemistry as his strong content topic and meiosis as his weak content topic; again, both of these topics were observed in the same section of students in a General Biology course for non-majors during the same semester. Interestingly, Jerry emphasized that he selected meiosis as his weak content topic because students did not do well on the exam for this topic, not because he felt he was weak in the content knowledge for this topic. Sheila's self-selected strong content topic was integumentary system, while her weak content topic was chemistry. These two topics were also observed in the same section of students enrolled in Anatomy and Physiology I during the same semester. Finally, Vera chose adaptive immunity as her strong content topic and attention/mood/behavior disorders as her weak content topic, which were both video-recorded in the same section of students for Pathophysiology in the same semester.

Additionally, semi-structured interviews were conducted before and after each observation. The pre-observation interviews were designed to ask questions about their planning for each lesson, while the post-observation interviews were designed to allow them reflection about the lesson. Finally, the researcher completed video-stimulated interviews designed to elicit reflections about specific examples of the participants' instructional strategies. Appendix C contains the finalized interview protocols.

Table 3.2

Summary of Content Topics Selected by Each Participant

Participant	Course	Strong Content Topic	Weak Content Topic
David	General Biology for Non-Majors	Genetics	Plant Evolution
Jerry	General Biology for Non-Majors	Chemistry	Meiosis
Sheila	Anatomy and Physiology I	Integumentary System	Chemistry
Vera	Pathophysiology	Adaptive Immunity	Attention/Mood/Behavior Disorders

Data were collected from multiple sources, including non-participant classroom observations, field notes, in-person semi-structured interviews, reflective research journal, and various types of instructional documents and artifacts. Table 3.3 summarizes the data sources and data analysis methods used to address each research question in this study (see Appendix D for more detailed list of data sources).

Table 3.3

Summary of Data Sources and Analysis Methods

Research Questions	Data Sources	Data Analysis Methods
1. What are the characteristics of PCK in community college biology instructors?	• preliminary background interviews • pre-observation interviews • post-observation interviews • video-stimulated interviews • non-participant classroom observations • field notes • instructional documents	• A priori code development using Pentagon Model of PCK • A priori coding of interview data • A prior coding of video-recorded observations
2. How does community college biology instructors' content knowledge (CK) relate to their PCK?	• pre-observation interviews • post-observation interviews • video-stimulated interviews • non-participant classroom observations • field notes • instructional documents	• A priori code development using Pentagon Model of PCK • A priori coding of interview data • A prior coding of video-recorded observations • Comparison of number and quality of PCK episodes between strong and weak CK • PCK map development for strong and weak CK
3. What sources do community college biology instructors use to develop PCK?	• preliminary background interviews • pre-observation interviews • post-observation interviews • video-stimulated interviews • non-participant classroom observations • instructional documents	• Open code development • Open coding of interview data • Open coding of video-recorded observations

Non-participant Classroom Observations. Direct observation was selected for this study as one method to capture data in real-time about each participant's characteristics of PCK and help the researcher to better understand how each participant's content knowledge is related to their PCK. Direct observation is an effective method of data collection because it provides an in-depth authentication of the here-and-now experience of the observed phenomenon. According to Guba and Lincoln (1981):

> observation … maximizes the inquirer's ability to grasp motives, beliefs, concerns, interests, unconscious behaviors, customs, and the like; observation …allows the inquirer to see the world as his subjects see it, to live in their time frames, to capture the phenomenon in and on its own terms, and to grasp the culture in its own natural, ongoing environment; observation … provides the inquirer with access to the emotional reactions of the group introspectively – that is, in a real sense it permits the observer to use *himself* as a data source; and observation … allows the observer to build on tacit knowledge, both his own and that of members of the group (p. 193).

In this study, the researcher asked each participant to select two topics in which their instruction was video recorded for analysis. Participants selected one topic in which they felt they had strong content knowledge and were highly confident in their teaching of the material. Additionally, participants selected a second topic in which they felt they had weaker content knowledge and were less confident in their teaching of the material. All classroom instructional time, in-class activities, laboratory sessions, and review sessions related to each of these two topics were video recorded for analysis. Each topic's presentation took a total of three to six hours of video recorded instructional time for each participant. The researcher did not participate in any classroom instruction, in-class activities, laboratory sessions, or review sessions. The researcher was present only to observe, make field notes, and video record each participant's presentation of their two selected topics.

Field Notes. During the in-person observations of each participant's lesson, condensed field notes were documented during the video recordings. Immediately after the video recording was completed, expanded field notes were written based on the condensed field notes of the observer. Maintaining field notes during the video recordings of each lesson was useful because it allowed the observer "to interpolate periods of preliminary data analysis between periods of observation" (Lincoln & Guba, 1985, p. 275).

In this study, field notes included the researcher's observations of the physical classroom settings, general characteristics of participants in the lesson, classroom activities, interactions, content of conversations, non-verbal behaviors, other classroom interactions that appeared significant to the researcher, and reflections of the researcher's own thoughts and behaviors.

Semi-structured Interviews. The semi-structured interview protocol was selected to address all three research questions in this study. According to Guba and Lincoln (1981), "in the [semi-]structured interview, the problem is defined by the researcher before the interview, [and] the questions have been formulated ahead of time, and the respondent's expected to answer in terms of the interviewer's framework and definition of the problem" (p. 155). Lincoln and Guba (1985) further emphasized that "the [semi-]structured interview is the mode of choice when the interviewer *knows what he or she does not know* and can therefore frame appropriate questions to find it out" (p. 269). In this study, each participant was asked to engage in three types of semi-structured interviews, including preliminary background interviews, pre-observation interviews prior to the video recordings of their lessons, and video-stimulated interviews after both lessons have been recorded. Table 3.4 shows an excerpt from the development process for the questions used in the structured preliminary background interviews (see Appendix B for complete process). Many of the interview questions were adapted from a research study of secondary biology instructors' PCK when teaching the lesson of natural selection conducted by Sickel and Friedrichsen (2018).

Table 3.4

How can I come to know my research questions?

Research Question	What do I need to know?	How can I know?	
		Possible Data Sources	Major Interview Questions
What are the characteristics of PCK in community college biology instructors?	What are some examples of PCK demonstrated by them in class?	• video recordings • video-stimulated interviews • observations • field notes • documents/artifacts	1. Why did you use these (insert strategies) to teach this topic? 2. Why did you decide to use this particular assessment strategy? 3. From your video and/or lesson plan, it appears that you chose to start the class (continue class; end the class) with (this strategy: warm-up, lecture, experiment, investigation, etc.). Why did you choose to start (continue; end) this way?
	What PCK components do they integrate into their lessons?	• preliminary background interviews • video-stimulated interviews	1. What were your purposes and goals for this lesson? 2. How does (this topic) fit into the "big picture" of what students learn about science in previous science courses and later science courses? 3. Describe how you assessed if students learned what you intended for (this topic). 4. How could you use (this representation or strategy) in a different way? Where did you learn to use it that way?
How do community college biology instructors' content knowledge relate to their PCK?	How did they become experts in their content areas?	• preliminary background interviews	1. What is your teaching philosophy? 2. What do you think is the best way(s) to engage students in learning about science? 3. Consider a typical day of teaching science. What is the teacher's role in a typical science lesson? What is the students' role in a typical science lesson?
What sources do community college biology instructors use to develop their PCK?	What are their sources of PCK?	• video-stimulated interviews • observations • field notes • documents/artifacts	1. How did you learn to teach this topic? 2. Where did you get your ideas for teaching this topic? 3. Tell me about the materials you prepared. Where did these materials come from? What modifications did you make to existing materials?

Note: Appendix B provides the full development process for each research question.

Preliminary background interviews. This is a semi-structured interview in which the questions were designed to collect background information regarding each participant's educational and professional experiences as well as their teaching philosophy and views about teaching and learning science in particular.

Pre- and post-observation interviews. The pre- and post-observation interviews were designed to be informal conversations that occur just before and immediately after the instruction period. The pre-observation was a semi-structured interview in which the questions were designed to discuss the planning decisions made for each lesson prior to instruction. The post-observation interview was also semi-structured in which the questions were designed to elicit reflective responses about the lesson immediately after it had concluded.

Video-stimulated interviews. After the lessons were video-recorded, they were coded using the a priori codes to identify interactions among the five components of PCK (see Data Analysis section), which were called PCK episodes. The video-stimulated interview was a semi-structured interview in which the questions were designed to elicit in-depth discussions regarding the PCK episodes identified during the a priori coding process and additional decisions made for teaching a particular lesson or topic.

Reflective Research Journal. Denzin (1994) referred to an "interpretive crisis" particularly related to qualitative research methodology. Ortlipp (2008) argued that "there is a lack of agreement on how much researcher influence is acceptable, whether or not it needs to be 'controlled,' and how it might be accounted for" during the analysis of data. Ortlipp (2008) suggested that maintaining a reflective research journal can make the researcher's "experiences, opinions, thoughts, and feelings visible and an acknowledged part of the research process". In order to address the issue of potential researcher influence and bias in this study, the researcher maintained a research journal of thoughts and reflections regarding various aspects of the research design and data collection processes. Each dated entry included the researcher's research decisions, emotional reactions, mistakes, questions, problems, thoughts about research methodolgy, as well as other reactions to the research process.

Documents and Artifacts. The researcher collected various instructional materials from participants, including lesson plans, presentations, test items, and handouts. Samples of students' work related to these topics may also have been provided with all identifying information removed so that the samples of work provided are anonymous. Documents and artifacts were useful sources of data for several reasons. According to Lincoln and Guba (1985), they are "almost always *available*" and serve as "a *stable* source of information, both in the sense that they may accurately reflect situations that occurred at some time in the past and that they can be analyzed and reanalyzed without undergoing changes in the interim" (p. 276-277). Lincoln and Guba (1985) further asserted that documents and artifacts "are a *rich* source of information, contextually relevant and grounded in the contexts they represent".

Data Analysis

Glaser (1965) first described the purpose of the constant comparison method of joint coding as a way "to generate theory more systematically … *by using explicit coding and analytic procedures*" (as cited in Glaser, 2008). He further asserted that "this method of comparative analysis is to be used jointly with theoretical sampling, whether for collective new data or on previously collected or compiled qualitative data" (as cited in Glaser, 2008).

In this study, the researcher adopted the open coding method for qualitative data analysis as described by Strauss & Corbin (1990) in order to analyze the data generated from the interviews and observations. Strauss and Corbin (1990) defined the process of open coding as "the analytic process through which concepts are identified and their properties and dimensions are discovered in data" (p. 101). They further described the process as identifying codes, defining their properties and dimensions, then looking for similarities and differences to identify themes.

Characteristics of PCK in Community College Biology Instructors. In order to address the first question in this study, the researcher used one participant's interview data to develop a priori subcodes based on the five components of the Pentagon Model of PCK for Science Teaching (Figure 2.1) previously described by Park and Oliver (2008a) and Park and Chen (2012). For example, the researcher developed multiple subcodes, related to one component of PCK (code), such as Knowledge of Assessment (KA). Subcodes for the code KA included examples of formative assessment techniques (FORM), summative assessment techniques (SUMM), and assessment of student facial expressions (FACE) to gauge understanding of a topic. Table 3.5 provides an excerpt from the a priori code book as an example of how a priori codes were generated (see Appendix E for complete a priori code book).

Table 3.5

Excerpt of A Priori Code Book

Code	Subcode	Definition	Example
Knowledge of Assessment of Science Learning (KA)	SUMM (**summ**ative assessment)	Describes an example of summative assessment	"I don't know if I can assess that until after they take the test, and see how successful it was"
	FORM (**form**ative assessment)	Describes an example of formative assessment	"I'm always asking them as I'm lecturing, "do you understand that?"
	FACE (**fac**ial expressions)	Describes reading facial expressions to gauge student understanding	"sometimes they'll give deer-in-headlights looks; so, I'll be like, "should we go over it again?"

Next, the researcher reviewed all the coded data for sections that were coded by two or more PCK codes and identified these combinations at interaction codes. Table 3.6 provides and excerpt from the interactions code book (see Appendix F for complete interactions code book). Each area of data coded with two or more interaction codes was counted as a PCK episode. The number of PCK episodes was tallied for each participant (see Table 4.1).

Table 3.6

Excerpt of Interactions Code Book

Interaction Code	Definition	Example
OTS – KISR	Orientation influences choice of instructional strategy	“here’s the concept that you can actually build this strand of DNA. And, you can watch these bands and like that just confirms the concept that made them fun”
KSU – KA	Knowledge of students’ understanding impacted assessment	“they just confuse all, all photosynthesis with being plant-related . . . I think I can see that in test and quiz questions where I will try to specifically ask about those things”
OTS – KSC – KISR	Orientation and knowledge of science curriculum impacts instructional strategies	“the pluripotent stem cell came from the current anatomy and physiology book . . . but it’s a document they’re familiar with from a previous class that they had. And, then I just add to it.”
KISR – KSU – KA	Knowledge of instructional strategies and students’ understanding impacts knowledge of assessment	“I always usually ask people . . . ‘Does that make sense? Do you understand that?’ And . . . look at their faces to see if they have the deer-in-headlight look. And, maybe I have to give another example from a different point of view for them to kind of understand that.”

Note: Appendix F provides the complete interactions code book.

Finally, the researcher compared the coded qualitative data among the four participants for similarities and differences in order to generate themes related to the characteristics of PCK. Additionally, once the important themes were identified, then the researcher discussed the theme development process and findings through a peer debriefing process with colleagues. For example, one theme identified from the similarities of all four participants was their limited use of formative assessment and strong utilization of summative assessment to measure student learning.

Relationship between CK and PCK in Community College Biology Instructors. In order to address the second research question in this study, the researcher used interview and observation data previously coded using the a priori codes and looked for similarities and differences in PCK between the stronger and weaker levels of content knowledge topics for each participant. The researcher previously defined PCK as the interaction between two or more components of the Pentagon Model of PCK for Science Teaching (Park & Oliver, 2008a). Using this definition of PCK, the researcher reviewed all the coded data for sections that were coded by two or more PCK codes. Areas of data that had been coded with two or more PCK component codes were counted as a PCK episode. The number of PCK episodes was tallied for each participant in both their strong content topic and weak content topic.

Next, the researcher assessed the quality of a PCK episode by counting the number of PCK components that were represented in each episode. Higher quality PCK episodes contained more PCK components. For example, a PCK episode that contained interactions among three components was considered a higher quality compared to an episode that contained interactions between two PCK components only. The researcher also created PCK maps showing the total number of interactions between PCK components for both the strong and weak content topics for each participant.

Finally, the researcher compared the number and quality of PCK episodes between the strong and weak content topics for each participant as well as among the four participants for similarities and differences in order to generate themes related to the relationship between content knowledge and PCK. Once the important themes were identified, then the researcher discussed the theme development process and findings through a peer debriefing process with colleagues. For example, the researcher identified that the number of PCK interactions differs between the strong and weak CK topics, but the quality of PCK (number of components involved in episode) among the five components is similar regardless of the level of content knowledge suggesting that content knowledge does not affect PCK in community college biology instructors.

Sources Used to Develop PCK in Community College Biology Instructors. In order to address the third research question in this study, the researcher identified various sources of PCK development based on original codes developed through the open coding process described by Strauss and Corbin (1990). The open codes were developed using an "in vivo" code naming strategy to best represent each source identified in the interview and observation data. Table 3.7 provides an excerpt from the open code book as an example of how open codes were generated (see Appendix E for complete open code book).

Table 3.7

Excerpt of Open Code Book for Sources of PCK

Code	Definition	Example
MOD (**mod**els instruction)	Model instruction after teachers from their own college courses	"the teachers that I had that I've kind of emulated my teaching methods after"
OBS (in person **obs**ervations)	Observation of other instructors in the classroom (in person)	"Working with other instructors"
TB (course **t**ext**b**ook)	Course textbook (publisher resources)	"First, I like to read the textbook just so that I see what the student is reading"
VID (**vid**eo explanations by other instructors)	Online videos about topics	"if I find a video that really brings things together like in ten minutes … I always put that on my site"

Note: Appendix E provides the complete open code book for sources of PCK.

Next, the researcher identified the similarities among the sources used by each participant to develop their PCK in order to generate themes regarding PCK sources. For example, one theme identified was the strong utilization of publisher resources to guide the development of instructional strategies.

Trustworthiness of Study

Lincoln and Guba (1985) argued that "the basic issue in relation to trustworthiness is simple: How can an inquirer persuade his or her audiences (including self) that the findings of an inquiry are worth paying attention to, worth taking account of" (p. 290). In order to address this issue, they asserted that researchers must address four criteria related to trustworthiness, including credibility, transferability, dependability, and confirmability.

Credibility. Lincoln and Guba (1985) posed the following question to address the "truth value" of the data analysis: "How can one establish confidence in the 'truth' of the findings of a particular inquiry for the subjects (respondents) with which and the context in which the inquiry was carried out?" (p. 290). They have connected this question to the conventional paradigm of internal validity. They specifically define internal validity as "the extent to which variations in an outcome (dependent) variable can be attributed to controlled variation in an independent variable" (p. 290).

Lincoln and Guba (1985) described several strategies to address credibility when collecting and analyzing qualitative data which were used in this study including prolonged engagement, persistent observation, triangulation, peer debrief, and member checks. Prolonged engagement is described as "the investment of sufficient time" in order to learn the culture and build trust with the participants (Lincoln & Guba, 1985, p. 301). Persistent observation added salience to the prolonged engagement technique by "identify[ing] those characteristics and elements in the situation that are most relevant to the problem or issue being pursued and focusing on them in detail" (Lincoln & Guba, 1985, p. 304). Triangulation referred to "the use of multiple and different sources, methods, investigators, and theories" (Denzin, 1978; Lincoln & Guba, 1985, p. 305). In this study, triangulation of multiple data sources and the use of several independent investigators (as in peer debriefs) were used to validate the research findings. Peer debriefing is "a process of exposing oneself to a disinterested peer in a manner paralleling an analytic session and for the purpose of exploring aspects of the inquiry that might otherwise remain only implicit within the inquirer's mind" (Lincoln & Guba, 1985, p. 308). In this study, the researcher used her doctoral advisor as a peer for these debriefing sessions throughout the data analysis. Finally, Lincoln and Guba (1985) argued that member checks are "the most crucial technique for establishing credibility" (p. 314). Member checks involve the "data, analytic categories, interpretations, and conclusion [being] tested with members of those stakeholding groups from whom the data were originally collected" (Lincoln & Guba, 1985, p. 314). In this study, participants were given an opportunity to review and assess the researcher's conclusions of their particular data analysis and provide confirmation and/or criticism of the researcher's results.

Transferability. Lincoln and Guba (1985) posed the following question to address the "applicability" of the data analysis: "How can one determine the extent to which the findings of a particular inquiry have applicability in other contexts or with other subjects (respondents)?" (p. 290). They have associated this question to the conventional paradigm of external validity. They accepted Cook and Campbell's (1979, p. 37) definition of external validity as "the approximate validity with which we infer that the presumed causal relationship can be generalized to and across alternate measures of the cause and effect and across different types of persons, settings, and times" (p. 291). Lincoln and Guba (1985) stated that the researcher must "provide only the thick description necessary to enable someone interested in making a transfer to reach a conclusion about whether transfer can be contemplated as a possibility" (p. 316). In this study, proper thick description included both "a thorough description of the context or setting within which the inquiry took place" and "a thorough description of the transactions or processes observed in that context [which] are relevant to the problem" (Lincoln & Guba, 1985, p. 362).

Dependability. Lincoln and Guba (1985) posed the following question to address the "consistency" of the data analysis: "How can one determine whether the findings of an inquiry would be repeated if the inquiry were replicated with the same (or similar) subjects (respondents) in the same (or similar) context?" (p. 290). They have associated this question with the conventional paradigm of reliability, which is interchangeable with "dependability, stability, consistency, predictability, [and] accuracy" (Kerlinger, 1973, p. 422). Ford (1975) suggested that "each repetition of the application of the same, or supposedly equivalent, instruments to the same units will yield similar measurements" (p. 324). Lincoln and Guba (1985) argued that "reliability is not prized for its own sake but as a precondition for validity" (p. 292); therefore, the same strategies described above for credibility and transferability also addressed the paradigm of reliability, including prolonged engagement, persistent observation, triangulation, peer debriefs, member checks, and rich description of the context, setting, and relevant observations.

Confirmability. Lincoln and Guba (1985) posed the following question to address the "neutrality" of the data analysis: "How can one establish the degree to which the findings of an inquiry are determined by the subjects (respondents) and conditions of the inquiry and not by the biases, motivations, interests, or perspectives of the inquirer?" (p. 290). They have associated this question with the conventional paradigm of objectivity. Since objectivity and subjectivity are often contrasted with each other, Lincoln and Guba (1985) refer to Scriven's (1971) "quantitative" comparison between these two terms which stated, "'subjective' refers to what concerns or occurs to the *individual* subject and his experiences, qualities, and dispositions, while 'objective' refers to what a *number* of subjects or judges experience – in short, to phenomena in the public domain" (p. 95). Therefore, Lincoln and Guba (1985) concluded that "if multiple observers can agree on a phenomenon [then] their collective judgement can be said to be objective" (p. 292), which is a method they termed intersubjective agreement.

Several strategies were implemented in this study to address confirmability including a confirmability audit coupled with triangulation and reflexive journaling. Please note that the triangulation technique has been previously described above when addressing the paradigm of credibility. Lincoln and Guba (1985) strongly supports Halpern's (1983) auditing procedures which include an audit trail with six categories including raw data, data reduction and analysis products, data reconstruction and synthesis products, process notes, materials relating to intentions and dispositions, and instrument development information.

Lincoln and Guba (1985) provide a description of materials that should be included in each of these six categories. *Raw data* includes "electronically recorded materials such as videotapes and stenomask recordings; written field notes, unobtrusive measures such as documents and records and physical traces; and survey results" (p. 319). In addition to these materials, audio recordings and transcripts of participants' interviews should also be included as raw data for this study. *Data reduction and analysis products* include "write-ups of field notes, summaries such as condensed notes, unitized information, … quantitative summaries, and theoretical notes" (p. 319). *Data reconstruction and synthesis products* include "themes, definitions, and relationships … interpretations and inferences … and a final report, with connections to the existing literature and an integration of concepts, relationships, and interpretations" (p. 319). *Process notes* include "methodological notes (procedures, designs, strategies, rationale); trustworthiness notes (relating to credibility, dependability, and confirmability); and audit trail notes" (p. 319). *Materials relating to intentions and dispositions* include "the inquiry proposal; personal notes (reflexive notes [known as the reflective research journal in this study] and motivations); and expectations (predictions and intentions)" (p. 320). Finally, the *instrument development information* includes "pilot forms and preliminary schedules; observation formats [interview protocols in this study]; and surveys" (p. 320).

Subjectivity Statement

Brandy Bowling. The researcher believes that learners construct and integrate their new knowledge into their current knowledge base. Therefore, educators should try to identify their students' pre-existing schemas as well as any existing alternate conceptions in order to design their instruction in ways that incorporate these schemas and address these alternate conceptions. The researcher thinks that students learn best from each other by working in pairs or small groups. Hence, the researcher views herself as a social constructivist.

The researcher's educational background is primarily in the biological sciences. Until her course work in this science education doctoral program, she had never considered issues of knowledge construction or best practices for teaching and learning science. Based on her coursework in the Science Education doctoral program, she has learned to create a student-centered classroom in which students are given opportunities to learn science in various ways, including the use of inquiry-based practices, cooperative learning groups, and multiple methods of information delivery (online and in-class resources). She also incorporates discussions of students' learning styles and various study strategies into every science course as a way to promote students' responsibility for their own learning of science. Given her student-centered view of learning, she must make sure that she recognizes any biased thoughts about teacher-centered instructional practices during the observations of her research participants and try to limit this bias during the data analysis process.

The researcher's primary role in the science department is a biology instructor. However, this science department is small enough for the researcher and her colleagues to share information about their lives both professionally and personally giving the researcher an opportunity to establish a good rapport with the research participants. Given these good working relationships, the researcher is hopeful that the participants were comfortable enough with her so that they did not change their teaching practices based on the researcher's presence in their classrooms. The researcher was hoping that they would try new strategies or activities in their lessons and not avoid doing this because of the researcher's presence as an observer. The researcher tried to avoid this pitfall by emphasizing her own excitement about the opportunities to see the participants in action and learn from them so that the participants understood their expertise in teaching science is valuable.

Many of the researcher's colleagues both within and outside of the science department were aware that the researcher was working on her doctoral degree in Science Education. Based on the researcher's educational pursuits, the Dean of the Arts and Sciences Division asked the researcher to co-chair a learning community designed for community college faculty from all disciplines to learn about and engage with different tools and teaching strategies with the ultimate goal of increasing student learning in all courses. During this time facilitating the learning community, many of the researcher's colleagues have come to view here as the "go-to" person for advice about different ways to teach their topics. This could pose an issue for the researcher's role as a neutral observer during the process of data collection. Since the participants were comfortable around the researcher, they asked for the researcher's feedback regarding their teaching practices. The researcher made it explicitly clear that the purpose of this research was to characterize their PCK and learn about the development of their PCK because they were the valuable expert science instructors.

Summary

In this chapter, the methodology used to answer the three research questions for this qualitative study was described in detail. First, a reflection of the researcher's epistemological view of social constructivism and ontological view of interpretivism in relation to this study were discussed. Next, the research design in this study was presented with a description of the research context, participants, data collection methods, data analysis methods, and trustworthiness of the study. Finally, the researcher's subjectivity statement was presented as a way to minimize any potential bias on the part of the researcher.

CHAPTER 4

RESULTS

The primary purpose of this study is to describe the characteristics of PCK in community college biology instructors. Additionally, this study aims to understand how content knowledge relates to their PCK and to characterize contributing sources used to develop their PCK. The Pentagon Model of PCK for Science Teaching described by Park and Chen (2012) was applied as the analytical framework to address the following research questions:

1. What are the characteristics of PCK in community college biology instructors?
2. How does content knowledge relate to PCK in community college biology instructors?
3. What sources do community college biology instructors use to develop PCK?

In this chapter, the results for each research question are described in detail. For each research question, several themes have been identified and supporting evidence for each theme is provided. First, three themes related to the characteristics of PCK in community college biology instructors are described. Next, two themes relevant to the relationship between content knowledge and PCK in community college biology instructors are reported. Finally, two themes related to the sources used by community college biology instructors to develop PCK are described.

Characteristics of PCK in Community College Biology Instructors

In this study, analysis of the data collected for research question one generated three themes related to the characteristics of PCK in community college biology instructors. First, the data revealed that these participants' preferred orientations of student-centered learning activities conflicted with their actual teacher-centered orientations. The second theme generated by the data showed these participants have less sophisticated overall PCK due to the weak connections among the five PCK components. Finally, the data revealed that these participants felt a time pressure to cover all material, which limited their potential types of instructional strategies. Qualitative results related to each of these themes is presented in the next three sections.

Theme 1. Preferred orientations conflicted with actual orientations. All four participants demonstrated didactic teacher-centered orientations during the video-recorded observations; however, each participant indicated that they believed students would learn better if more student-centered activities were incorporated into the classroom. For example, during the preliminary background interviews of all four participants, each participant described their beliefs that student-centered activities increased learning about science. Sheila's comment on the use of hands-on activities to practice the science content below nicely captured this feature.

> *I also like hands-on stuff where you get to experiment, and see 'oh, this works; this doesn't work. Why didn't this work? Let's figure out the answer to that' – kind of thing. So, I try to apply those same methods to the students as well* (Sheila, preliminary background interview).

Similarly, Vera explained the use of student-involved demonstrations as a way to physically engage students in the learning process of science content, stating,

> *A lot of times I do demonstrations, and I will ask for participants from the audience . . . . I do the transcription dance when we talk about transcription and translation. And, somebody's the ribosome, you know. And, we have transfer RNA coming in, and we do high fives when we make a peptide bond* (Vera, preliminary background interview).

Although all participants described student-centered learning as their ideal instructional practice, they all demonstrated primarily didactic orientations in the classroom with teacher-centered lecture as the primary mode of knowledge transmission. Magnusson, et al. (1999)

identified the primary goal for teachers with didactic orientations as simply transmission of scientific facts. Furthermore, they described the characteristics of instruction for teachers with didactic orientations as “present[ing] information, generally through lecture or discussion, and questions directed to students [which] are to hold them accountable for knowing the facts produced by science” (Magnusson et al., 1999, p. 101). The following description of David’s teaching about the topic of plant evolution exemplified the actual didactic orientations depicted in each video-recorded observation for all participants.

As students entered the classroom several minutes before the start of class, David prepared the classroom for his lecture by powering up the computer, *downloading the topic-specific powerpoint presentation, and writing some key vocabulary terms on the white board* (researcher’s field notes, 11/6/17). Students prepared for class to begin by *setting up their laptops and taking out paper to write down notes while putting away their bookbags and cell phones. Some of the students also had their textbooks open to the plant chapter* (researcher’s field notes, 11/6/17) which was being presented in lecture. David started the class with several administrative duties, such as marking attendance and highlighting important upcoming due dates for assignments, labs, and/or test dates. *Once these administrative duties were completed, David asked students about their current knowledge of plants and their thoughts about the importance of plants. After this short discussion, David then lectured about plant evolution using the powerpoint as a guide* (researcher’s field notes, 11/6/17) for the order in which the plant information was delivered. David also wrote down a few details related to the vocabulary he had listed on the white board prior to class. All *students sat quietly while listening to David’s lecture* (researcher’s field notes, 11/6/17). Some students were typing and/or writing notes, and other students highlighted relevant text in their biology textbooks. Students *did not interrupt the* *lecture with any questions about the material* (researcher's field notes, 11/6/17). As the end of the class time approached, David allowed about three minutes for students to ask questions about any content that they did not understand. *During this time, most students began packing up and prepared to leave without asking any questions* (researcher's field notes, 11/6/17).

As evident in the description above, David's instructional strategy of using lecture as the primary form of knowledge transmission was typical of the way all four participants organized their classroom presentations. In all teaching observations, the instructor was standing at the front of the classroom next to a whiteboard either writing notes on the whiteboard, referring to a powerpoint presentation projected onto the whiteboard, or some combination of these two modes of information delivery. This type of classroom setup and delivery of content is the epitome of teacher-centered instruction. One participant, Jerry, explained his predominant use of teacher-centered instruction in the following way,

> *I have never been modeled anything other than a traditional lecture. I have never seen another way of teaching . . . . So, my philosophy is stay with that, but incorporate some of the new things like internet. But, have [lecture] be the core; here's the information you need to know* (Jerry, preliminary background interview).

Although they all indicated in their interviews that they believed students would learn better if more student-centered activities were incorporated into their science classrooms, the four participants clearly exhibited didactic teacher-centered orientations described by Magnusson et al. (1999) as the predominant use of lecture to transmit scientific facts. Hence, their preferred orientations of student-centered learning clearly conflicted with their actual didactic orientations.

Theme 2: Weak connections among components indicated less sophisticated PCK. In this study, PCK was defined as the interactions among the five components of PCK described in the Pentagon Model of PCK in Science Teaching (Park & Chen, 2012). Therefore, in this study, PCK episodes were described as an interaction between two or more components of PCK in science teaching as previously defined by Park and Oliver (2008a) and Park and Chen (2012). Weaker, less sophisticated PCK episodes involved only two or three components, while stronger, more sophisticated PCK episodes involved four or five components. Table 4.1 summarized the frequency of PCK episodes and indicated number of components involved in these PCK episodes for each of the four participants.

Table 4.1

Frequency and Quality of PCK Episodes for All Participants

Participant	Total Number	Number of Components Involved in PCK Episode			
		2 components	3 components	4 components	5 components
David	16	15	1	0	0
Jerry	18	18	0	0	0
Sheila	9	9	0	0	0
Vera	21	13	8	0	0

Additionally, Table 4.2 cataloged the frequency and type of both 2-component and 3-component interactions involved for each PCK episode observed in all participants (see Appendix F for frequency of all potential interaction combinations).

Table 4.2

Frequency and Type of Interactions Involved in PCK Episodes for All Participants

Interactions with 2 Components	Frequency	Interactions with 3 Components	Frequency
OTS – KSU	8	OTS – KSU – KISR	1
OTS – KISR	15	OTS – KSU – KSC	1
OTS – KSC	1	OTS – KSU – KA	2
OTS – KA	8	OTS – KISR – KSC	1
KSU – KISR	6	OTS – KISR – KA	1
KSU – KSC	2	KISR – KSU – KSC	1
KSU – KA	7	KISR – KSU – KA	2
KISR – KA	8		
KSC – KA	1		

Note: Appendix F provides the complete interactions code book.

Both Table 4.1 and Table 4.2 showed that all PCK episodes demonstrated by the participants involved either two or three components indicating all participants had weaker, less sophisticated overall PCK.

In addition, Table 4.3 summarized the frequency each individual component was involved in PCK episodes; the PCK components are listed in Table 4.3 from most frequent to least frequent.

Table 4.3

Frequency of Individual Component's Involvement in PCK Episodes for All Participants

PCK Component	Total Number	Components Involved in PCK Episodes			
		David	Jerry	Sheila	Vera
OTS	38	11	10	4	13
KISR	35	10	8	5	12
KSU	30	5	5	7	13
KA	29	7	9	4	9
KSC	7	0	4	0	3

Table 4.3 demonstrated that these participants primarily integrated only four of the five PCK components into their weaker overall PCK. These four components included OTS (38 episodes), KISR (35 episodes), KSU (30 episodes), and KA (29 episodes). The KSC component (7 episodes) was rarely integrated into overall their PCK. In the following section, results related to the individual characteristics of all five PCK components presented.

Characteristics of OTS. In regards to OTS, all participants indicated that the student was primarily responsible for their own learning, while the instructor's primary role was to provide students with information and resources. This orientation implied that teaching can occur even if learning does not. For example, Jerry emphasized, "*Here's the information you need to know, and it's up to you as the student to … figure it out*" (Jerry, preliminary background interview). Similarly, Vera indicated "*I want you to be successful, and I will provide this for you; it's up to you to take advantage of it*" (Vera, preliminary background interview). Sheila elaborated, *"A student's role is to be engaged, to be in attendance . . . . And, they need to know that they're not going to pass this class if they only do something in the class; they have to have time outside of class to prepare and to study*" (Sheila, preliminary background interview). David emphasized to his students that he "*want[ed] them to realize they have to be active participants, that they're* *just not going to be a passive receptacle and absorb what [he's] throwing at them*" (David, preliminary background interview).

Additionally, these comments also suggested most participants primarily viewed themselves as a source of scientific information and resources, rather than as facilitators of science knowledge. Jerry explicitly described this role in his comment, "*So I am old school in that the teacher is the disseminator of the information*" (Jerry, preliminary background interview). In contrast, David was the only participant who explicitly described his role as a facilitator of learning for the student in his comment, "*I don't want to say so much as, 'I am teaching you this.' I almost say sometimes like, 'I'm assisting you in your learning'*" (David, preliminary background interview).

While the participants described themselves as facilitators of learning, they rarely demonstrated this role. For example, Vera commented that the teacher's role was "*to break down concepts so that the students can understand them*" (Vera, preliminary background interview). Occasionally, Vera used analogies she thought the students would be familiar with in order to describe physiological processes in the human body as illustrated in her comment below.

> *When I teach, especially when it's something really hard, I always try to relate it to, or assimilate it to, something that a student might be familiar with. So, for example, when we talk about phagocytosis, we talk about pac-man and 'chomp, chomp, chomp', and eating up the pathogen* (Vera, strong pre-observation interview).

Similarly, Jerry explained that the teacher should be the expert in every topic so the students would remain engaged with the material as illustrated in his comment below.

> *If there is a subject I am not familiar with, I will make sure I'm the expert in it. I truly believe that the teacher should have a solid grasp of every topic . . . . I believe when a*

> *student has a question you just can't answer, but you don't know – it just diminishes you in their eyes and then respect goes down and they stop listening* (Jerry, preliminary background interview).

Jerry also emphasized that part of his role as expert included explanations of scientific concepts that addressed applications and relationships among the content demonstrated in his comment, "*What do the words mean? How do they apply? And, you know, why does x relate to z?*" (Jerry, preliminary background interview). The comments above indicated the participants have weak understandings of both the connection between teaching and learning as well as what it means to be a facilitator of science knowledge, which demonstrated less sophisticated OTS component contributing to weaker overall PCK.

Characteristics of KISR. Regarding the KISR component, all participants demonstrated a limited range of instructional strategies. They primarily relied on teacher-centered lectures as a method of science knowledge transmission. The following description of Vera's teaching of adaptive immunity exemplified the teacher-centered instructional strategy demonstrated in each video-recorded observation for all participants.

Prior to the start of class, *Vera prepared the classroom by writing notes on the board and leaving space to fill in the additional notes later as she presented her lecture on adaptive immunity. Students filtered into the classroom, took out textbooks, notebook paper, and writing instruments* (researcher's field notes, 6/1/2017). The class session began with some administrative duties, such as attendance and test reminders. After Vera addressed some student questions related to upcoming assignments, she then began her lecture on adaptive immunity. Throughout her lecture, she referred constantly to her own handwritten notes to guide her presentation of the material. Students sat quietly taking notes until it was time for the first break.

Vera gave students an opportunity to ask questions before break and again when they returned from break. No questions were asked during this time. After break, Vera continued with her lecture on adaptive immunity as before by referring constantly to her own handwritten notes to guide her presentation as she added material to the outline on the board. She periodically paused to ask students if they understood the material. There was no verbal indication from the students whether or not they understood. Vera assumed this lack of response coupled with no questions being asked from the students as an indication that they understood the material, and she proceeded with the next part of the lecture. Approximately five minutes before the end of the class period, Vera ended the lecture and allowed time for students to ask questions. No questions were asked during this time, and students began to put away their things in preparation to leave.

Vera's teacher-centered lecture described above was typical of the primary instructional strategy demonstrated by all four participants during their video-recorded observations. It is evident that these instructors have limited understandings of various types of instructional strategies for teaching science, which demonstrated a weaker KISR component contributing to less sophisticated overall PCK.

Characteristics of KSU. In regards to the KSU component, all participants recognized the wide range of students' initial understandings for any content, which played a limited role in the design of the instruction. This is most obvious in Sheila's comments below about how her students' initial knowledge affected her planning decisions for chemistry.

> *Plus, knowing that the students are going to have varying levels of knowledge in this topic, I don't want to bore students who have had a lot of chemistry . . . And to those that give me the 'deer-in-headlight' look, like, . . . I have no idea what you're talking about.' I kind of have to find a happy medium* (Sheila, weak pre-observation interview).

Similarly, David emphasized how little his students already knew about plants, even though some students may know more than others, stating,

> *I think they know basic stuff. You know, like, if they walk up to a tree, they know that's a plant. But, they, most of them have no idea what kind of tree it is . . . it's a big opportunity to teach them about something* (David, pre-weak observation interview).

Additionally, Vera described her use of visual materials from a pre-requisite course to activate prior knowledge in her pathophysiology students, stating,

> *So the pluripotent stem cell came from the current anatomy and physiology book that we are using. And, it doesn't have everything on it but it's a document they're familiar with from a previous class that they had. And, then I just add to it . . . . So, most students would have seen that picture in pathophysiology because they had it in the previous class* (Vera, strong pre-observation interview).

Clearly, these participants demonstrated recognition of students' different levels of prior knowledge, which weakly influenced instructional decisions made for their courses. It is important to note these instructors recognized the diversity of their students' levels of prior knowledge, but they did not attempt to identify misconceptions or use different instructional strategies based on this prior knowledge. Hence, the limitations of their KSU component contributed to the overall weaker PCK.

Characteristics of KA. Regarding KA, all participants illustrated a heavy reliance on summative assessment measures with minimal use of formative assessment strategies. For example, all participants described their use of multiple-choice and short answer exams as their primary tool for measuring student learning. Jerry indicated that his "*exams are purposefully very difficult*" (Jerry, preliminary background interview) so he did not use any other type of assessment because "*all of [his] educational experience has been lecture-exam*" (Jerry, strong pre-observation interview). Sheila equated passing a test with learning the material, but she didn't agree that multiple choice questions were the best way to test students' understanding as indicated in her comment, "*I passed a test; I learned it. Well, I don't necessarily agree with that. I think it's part of it because I think you're grasping the material, but if you're just picking answers out of a multiple choice, guessing could be a part of that as well*" (Sheila, preliminary background interview). However, in practice, Sheila designed multiple choice tests with a few short answer and short essay discussion questions. Additionally, all four participants demonstrated a limited use of formative assessment measures. Their formative assessment techniques primarily centered around asking if students understood the material being presented and reading their facial expressions for any confusion. For example, Vera commented, "*If you get the 'deer-in-headlight' look from everyone in class then you know . . . the concept is so over their heads that you kind of have to back up and break each part of it down a little bit more*" (Vera, preliminary background interview). Jerry reiterated those students who are not familiar with the content will "*look like they're shell-shocked*" (Jerry, strong pre-observation interview).

Characteristics of KSC. In regards to KSC, only two of the four participants described how their knowledge of science curriculum influenced their overall course design. For example, Jerry emphasized his understanding of horizontal curriculum within the same course by his comment, "*without having the foundation, what is an atom, what is a molecule, you can't appreciate the rest of it like DNA and proteins and how they help to, you know, determine the function of an organism*" (Jerry, strong pre-observation interview). Additionally, Vera explained her understanding of vertical curriculum as a consideration for course material in her comment below.

If you're taking A&P one and A&P two, chances are that you're going into the nursing program, your next prerequisite is pathophysiology so I'm not going to teach you part of it in A&P two, and then say 'oh remember when we learned this, well now we're going to add some more stuff to it.' I'm just going to do it right off the top. And, I tell them that. I tell them that in A&P two. It's like 'look, I'm going to tell you more stuff than is in your book just because I know you are going to need to know it.' (Vera, strong pre-observation interview).

Given the limitations for each of the five individual PCK components described for these participants, it was not surprising to see weaker, less sophisticated overall PCK. The data supported this assertion by the participants' weak connections between teaching and learning (OTS), limited range of instructional strategies (KISR), limited application of prior student knowledge (KSU), heavy reliance on summative assessment (KA), and limited consideration of curriculum in their course design (KSC).

Theme 3: Time exerted an external pressure on PCK by limiting potential instructional strategies. All four participants discussed how the pressure of time available for covering the required material affected the type of instructional strategies they used in both their classroom and/or laboratory sessions. For example, David discussed time in his comment below as one of his important considerations when he's planning to teach a topic.

Trying to figure out the amount of information, the level of details; kind of like in the time frame that I have, what can I accomplish? So that to me is a big deal. It's like I can have all these aspirations about like we're going to learn about PCR today. You know, it'd be awesome if they really understood it, but if you've never done it and you've never heard of it; you're not going to learn it from me just describing it to you in 20 or 30 minutes, or *probably even 50 minutes . . . . But, like what can you do with that information, how powerful that is? And then, figure out how I'm going to squeeze it into the time that I have* (David, preliminary background interview).

Similarly, Jerry discussed his time limitation for implementing new instructional strategies that he had learned at professional development seminars in his comments below.

The ideas are there, but to actually implement those; I always don't have the time to do [it] *. . . . I wish I had more time to play with them but, yeah so, I have the content, finding different ways to deliver the content is important for me to know* (Jerry, video-stimulated interview).

Additionally, Vera also discussed time as a factor in her selection of presentation tools in her comment, "*I'll use powerpoint if there's a lot of pictures and I don't feel like I have enough time to draw everything* (Vera, preliminary background interview). Finally, Sheila best summarized the frustrations felt by all of the participants due to time limitations in her comment below.

Unfortunately, I have to think of time because we're limited with how much time we have in the classroom or in the lab . . . . And, sometimes it's very frustrating because I think I don't give it justice because I don't have enough time (Sheila, preliminary background interview).

All participants clearly indicated that limited amounts of time strongly influenced their choice of instructional strategies used in their science classrooms, limiting their overall PCK by directly impacting the KISR component.

Relationship between CK and PCK in Community College Biology Instructors

In this study, analysis of the data generated two themes pertaining to the relationship between content knowledge (CK) and PCK in community college biology instructors. First, the participants' PCK looked similar for both strong and weak content knowledge. This indicated that content knowledge did not significantly affect PCK. Secondly, each individual component of PCK also looked similar for both strong and weak content knowledge for each participant, suggesting that content knowledge did not impact the individual components of PCK or the interactions among the components. Evidence drawn from data that supports these two themes is discussed in the next two sections.

Theme 1: Content knowledge did not significantly affect PCK. All four participants demonstrated similar PCK between their strong and weak content knowledge topics. Regardless of the content presented, all participants demonstrated weaker, less sophisticated PCK, which implied that content knowledge did not affect PCK for these instructors.

Recall that PCK episodes were defined as an interaction between two or more components of PCK in science teaching as described by Park and Oliver (2008a) and Park and Chen (2012). Stronger, more sophisticated PCK episodes involved four or five components, while weaker, less sophisticated PCK episodes involved two or three components. One example of a PCK episode involving two components was illustrated by Jerry's explanation that distinguishing between sister chromatids and homologous chromosomes (KSU) helped students to more easily understand the processes of mitosis and meiosis (KSC). Jerry said, "*the idea that you can have sister chromatids, but the two are still one pair of homologous chromosomes. So, I emphasize that a lot because I feel like if they get that distinction, it makes mitosis and meiosis really easy*" (Jerry, weak pre-observation interview). Furthermore, Vera illustrated an example of a PCK episode involving three components in her comment below.

> *I always usually ask people as I go along, 'Does that make sense? Do you understand that?'* [KA] *And, kind of you know, look at their faces to see if they have the deer-in-*

headlight look. [KA] *And, maybe I have to give another example* [KISR] *from a different point of view* [KSU] *for them to kind of understand that.* (Vera, weak pre-observation interview).

All four participants demonstrated weaker, less sophisticated PCK in both their strong and weak content topics. Table 4.4 compared the number of PCK episodes for strong content and weak content topics, while Table 4.5 summarized the quality of the PCK episodes for both strong and weak content topic by indicating the number of components involved in the PCK episodes for all four participants.

Table 4.4

Number of PCK Episodes in Strong and Weak Content for All Participants

Participant	Strong Content Topic	Weak Content Topic
David	3	7
Jerry	5	6
Sheila	2	4
Vera	11	4
Total	21	21

As seen in Table 4.4, David, Jerry, and Sheila had more PCK episodes in their weak content topic, while Vera had more PCK episodes in her strong content topic. However, the total number of PCK episodes for all four participants was equal for between the strong and weak content topics. More importantly, it was noted that although the participants showed minor differences in the number of PCK episodes between their strong and weak content topics, the quality of the PCK interactions was similar as shown in Table 4.5.

Table 4.5

Quality of PCK Episodes in Strong and Weak Content for All Participants

Participant	Number of Components Involved in PCK Episode	Strong Content Topic	Weak Content Topic
David	2 components	3	7
	3 components	0	0
	4 components	0	0
	5 components	0	0
Jerry	2 components	5	6
	3 components	0	0
	4 components	0	0
	5 components	0	0
Sheila	2 components	2	4
	3 components	0	0
	4 components	0	0
	5 components	0	0
Vera	2 components	6	3
	3 components	5	1
	4 components	0	0
	5 components	0	0
Total	2 components	16	20
	3 components	5	1
	4 components	0	0
	5 components	0	0

All four participants demonstrated less sophisticated PCK in both their strong and weak content topics because all PCK episodes involved only two or three PCK components. Most of the PCK episodes involved only two components of PCK regardless of the type of content topic as shown in Table 4.5. Furthermore, Figure 4.1 compared the overall PCK maps between strong and weak content topics for each participant. The numbers on the inside of the map indicated the number of interactions between two components, while the numbers on the outside of the map indicated the total number of times each component was involved in an interaction.

As seen in Figure 4.1, A comparison of the strong and weak overall PCK maps for David showed that his PCK episodes for both strong and weak topics involved the same four components (OTS, KSU, KISR, & KA). Similarly, both Jerry's strong and weak overall PCK maps both involved all five PCK components. However, a comparison of Sheila's overall PCK maps showed that her weak content topic involved four components (OTS, KSU, KISR, & KA), but her strong PCK involved only two components (KSU & KISR). In contrast, Vera's PCK maps showed that her strong content knowledge involved all five PCK components, while her weak PCK map involved four components (OTS, KSU, KISR, & KA).

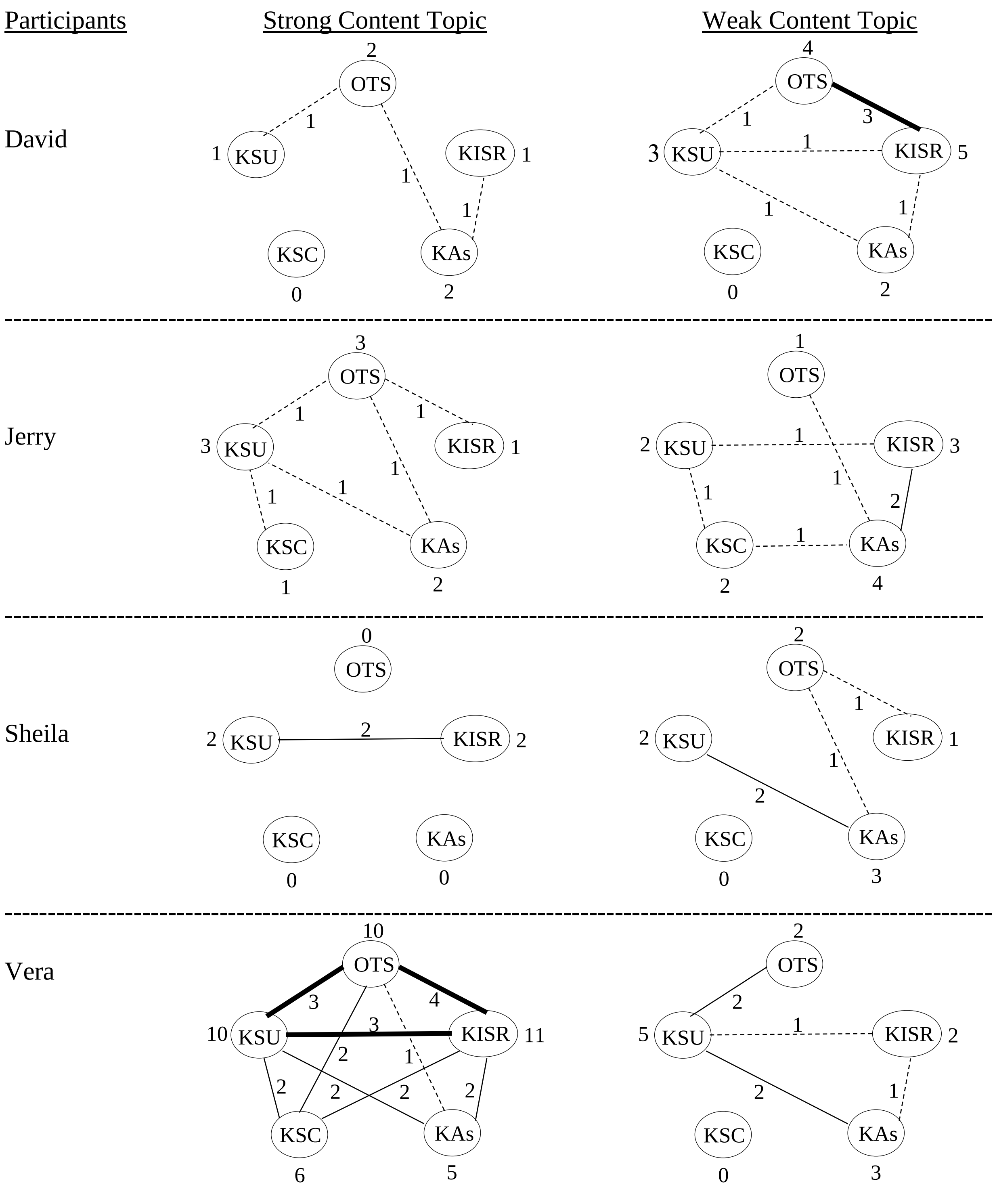

Figure 4.1. Comparison of PCK Maps for Strong and Weak Content Knowledge. This figure compares the overall PCK Maps between strong and weak content topics for each participant.

Number of interactions: 0 no line 1 - - - - 2 ——— 3-4 ▬▬▬

Taken together, the equal number of PCK episodes between strong and weak content, the similar quality of PCK interactions between strong and weak content, and the comparisons of overall strong and weak PCK maps indicated that content knowledge did not significantly impact overall PCK for each participant.

Theme 2: Content knowledge did not impact individual PCK components or their interactions. Individual components of PCK and the interactions among the component looked similar for each participant's strong and weak content knowledge, suggesting that content knowledge did not impact the individual components of PCK. Table 4.6 summarized the number of times each component was involved in a PCK episode for strong and weak content topics. The components have been listed in order from highest to lowest frequency.

Table 4.6

Frequency of Each Component in PCK Episodes for All Participants

PCK Component	Strong Content	Weak Content	Total
KSU	11	11	22
KISR	12	10	22
OTS	11	9	20
KA	8	11	19
KSC	4	2	6

Table 4.6 clearly shows the similarity in frequency for each component that was involved in PCK episodes between strong and weak content topics, indicating that content knowledge had no effect on each individual component of PCK. Additionally, Table 4.6 indicated that these four participants integrated four components of PCK most often regardless of content knowledge. These four components included KSU (22 episodes), KISR (22 episodes), OTS (20 episodes), and KA (19 episodes). In contrast, these participants rarely integrated the KSC

component (6 episodes) into their overall PCK. Therefore, in this section, only results related to the effect of content knowledge on components KSU, KISR, and KA are presented. Please recall that the participants' orientation to science teaching (OTS) was previously described in the results as didactic teacher-centered orientations for both strong and weak teaching demonstrations.

Content knowledge and KSU. In regards to the KSU component, all participants demonstrated simple recognition of where their students may have been previously exposed to the strong and weak content topics. For example, Jerry explained his ideas about his students' previous exposure to meiosis, stating,

> *Usually, I get the sense that students have heard it. They associate it with sperm and eggs. Usually, you're like, "what do you, if you say meiosis, what?" And, they're like, "sperm and eggs!" How does it work? We have no idea. So, then, that it has something to do with sex, but that's it. Probably, what they've been taught in high school or middle school or . . . previous K through 12* (Jerry, weak pre-observation interview).

Similarly, Vera elaborated about her students' exposure to adaptive immunity in her comments below.

> *Because I think in the past, they've not really had a strong class, either in high school or maybe not here, that explained it to them very well. Because it is a hard subject if you get a teacher that if it's not their favorite subject, they're not going to go into a lot of depth in it . . . . If somebody is in the nursing program, they might have had some of it in one of their classes. Biology 163 and Biology 169 are prerequisites for the class so I know it's in Biology 169 curriculum, but I've not taught Biology 163 so I don't know how in-depth they go into it* (Vera, strong pre-observation interview).

Additionally, all participants recognized the diversity of their students' initial understandings for both the strong and weak content topics. For example, Sheila discussed her the role that students' prior knowledge made in her planning decisions for chemistry in the following comments.

> *Plus, knowing that the students are going to have varying levels of knowledge in this topic, I don't want to bore students who have had a lot of chemistry and are like, 'oh my god, I have to go through this again.' And to those that give me the 'deer-in-headlight' look, like, 'this is a foreign language that you're speaking and I have no idea what you're talking about.' I kind of have to find a happy medium* (Sheila, weak pre-observation interview).

Similarly, David emphasized how little his students already knew about plants, even though some students may know more than others, stating,

> *I think they know basic stuff. You know, like, if they walk up to a tree, they know that's a plant. But, they, most of them have no idea what kind of tree it is. This distinction between an oak tree and a pine tree and a fern. Things like that. So, it's an awful, it's a big opportunity to teach them about something* (David, pre-weak observation interview).

Taken together, the participants' recognition of prior content exposure in their students and the diversity of their students' prior understandings of the material regardless of the type of content demonstrated that content knowledge did not impact KSU.

Content knowledge and KISR. In relation to the KISR component, several common characteristics were observed for all participants during every teaching demonstration, regardless of the content type (strong or weak). For example, in all teaching observations, the instructor was standing at the front of the classroom next to a whiteboard. Additionally, David, Jerry, and

Sheila each used the same presentation method regardless of the content topic, while Vera's choice of presentation method was based on her confidence (strong or weak) of the content knowledge. Regardless of the type of presentation method used, they all used the same type of instructional strategy to deliver both the strong and weak content topics, which was teacher-centered lectures.

David used a combination of powerpoint and guided notes written on the board to present both his strong and weak content topics. The researcher commented on the similarities between his strong and weak teaching demonstrations in the statement, "*Similarly to his strong topic, David set up the classroom by downloading the topic-specific powerpoint presentation and writing some key vocabulary terms on the white board*" (researcher's field notes, 11/6/17). Jerry's teaching demonstrations were very similar to David's in that he also used powerpoint presentations to guide the lecture for both content topics. The researcher noted in Jerry's strong observation part one that "*the classroom was very dark with only the powerpoint being projected onto the whiteboard*" (researcher's field notes, 8/23/17). Again, the researcher noticed in Jerry's weak observation part one that he "*presented the material about meiosis using primarily a powerpoint edited for content in a dark room*" (researcher's field notes, 10/17/17).

In contrast to David and Jerry, Shelia presented her information for both topics by writing notes on the board. Prior to each observation for both strong and weak content topics, Sheila "*outlined the topics she planned to cover on the board leaving space to fill in information as she lectured*" (researcher's field notes, 8/15/17). The researcher noted the similarity in Sheila's presentation methods for both strong and weak content topics as stated in the comment "[Sheila's] *presentation style looks just like her weak CK*" (researcher's field notes, 9/19/17).

Finally, Vera was the only participant that demonstrated differences in presentation tools based on her content topic; however, both tools were used as part of teacher-centered lectures. Vera presented her information for her strong content topic using both written notes on the board and powerpoint presentation, but she presented information for her weak content knowledge using only a powerpoint presentation. The researcher noted this difference in presentation method during her reflections immediately after Vera's weak observation had been initially video-recorded. The researcher commented, "*the biggest difference here was the use of the powerpoint to deliver information about mood, behavior disorders*" (researcher's field notes, 6/22/17) compared to the presentation of the strong content knowledge. Vera presented her strong content knowledge "*by writing notes on the board and leaving space to fill in the additional notes later as she presented her lecture on adaptive immunity*" (researcher's field notes, 6/1/17). Clearly, the primary instructional strategy regardless of content topic was teacher-centered lectures. Based on these similarities between their strong and weak content topics, content knowledge did not impact KISR.

Content knowledge and KA. In regards to the KA component, all four participants discussed the primary use of summative assessments, including quizzes and exams, as the primary measurement tools for students' learning of the material regardless of content knowledge type (strong or weak). Additionally, participants used limited formative assessments, such as reading facial expressions, to measure students' understanding of the content.

All four participants discussed the use of exams to measure student learning at the end of each content topic. For example, David described a specific example of information measured using summative assessments in his comment, "*they just confuse all, all photosynthesis with being plant-related . . . I think I can see that in test and quiz questions where I will try to* *specifically ask about those things*" (David, weak pre-observation interview). Similarly, Jerry emphasized, "*my assessment is really the exam at the end of the whole section*" (Jerry, strong pre-observation interview), and he further explained how he learned his assessment techniques in his comment "*all of my educational experience has been lecture-exam. Like, I have not as a student, I didn't experience anything other than that*" (Jerry, strong pre-observation interview). Finally, Sheila described the use of summative assessment to identify student difficulties with the content in her comment, "*difficulties would be not doing well on the exams. And, hopefully, I would know that they didn't understand it before we get to that point because we're trying to prevent that from happening*" (Sheila, strong pre-observation interview).

All four participants relied heavily on reading students' facial expressions as a method of formative assessment regardless of their type of content topic. For example, Vera discussed how she gauged students' understanding during her strong content lectures when she stated, "*I'm always asking them as I'm lecturing, 'do you understand that?' And, sometimes they'll give 'deer-in-headlight' looks; so, I'll be like, 'should we go over it again?'*" (Vera, strong pre-observation interview). Similarly, Vera assessed students' facial expressions during her weak content lectures as well when she explained, "*I always usually ask people as I go along, 'Does that make sense? Do you understand that?' And, kind of, you know, look at their faces to see if they have the 'deer-in-headlight' look*" (Vera, weak pre-observation interview). Furthermore, Sheila observed, "*I've just noticed from just teaching in general if the topic when we're discussing it is not working for them or they don't understand it, you just get weird looks. It's hard to explain the look, but it's there. And, so I typically ask, 'do we need to go over that again?'*" (Sheila, strong pre-observation interview). Jerry summarized how he was able to gauge students' understanding of a particular topic when he commented, "*it's just interaction with the* *student face-to-face. I can see it. The ones that have had it, they look comfortable. And, the ones that have not had it, they look like they're shell-shocked*" (Jerry, strong pre-observation interview). Clearly, the similarities in the participants' assessment choices between the strong and weak content topics indicated that content knowledge did not impact KA.

These results clearly demonstrated that content knowledge did not impact the individual KSU, KISR, or KA components of PCK. First, all participants recognized in their students any prior exposure to content and the diversity of students' prior understandings of the material before teaching either strong or weak content topics; thus, content knowledge did not impact KSU. Next, all participants used teacher-centered lectures as the primary instructional strategy to deliver both their strong and weak content topics, which demonstrated that content knowledge did not impact KISR. Finally, the participants' limited use of formative assessment strategies and heavy emphasis on summative assessment strategies also indicated that content knowledge did not impact KA.

Sources Used to Develop PCK in Community College Biology Instructors

Analysis of the data revealed two themes related to the sources used to develop PCK in community college biology instructors. First, the participants relied heavily on multiple online sources, such as internet searches and online videos, and publisher-developed materials, such as the course textbook, to guide the instructional design of their courses. Hence, this strong utilization of online and publisher-developed sources primarily impacted the KISR component of their PCK. Second, the participants demonstrated an acute interest in participating in professional development activities mainly related to the implementation of different types of instructional strategies, which in turn would improve their overall PCK. Evidence supporting these two themes is described in the following two sections.

Theme 1: Strong utilization of online and publisher-developed sources impacted KISR. All participants discussed how they used the course textbook as the predominant guide to the development of their lecture materials. Additionally, they also relied heavily on general internet searches for any necessary clarifications of their content knowledge about course topics. Furthermore, the participants also completed general internet searches for ideas about how to present the material to students, such as video recordings of other instructors' presentations of similar content. Table 4.7 summarized the codes most often used during the open coding process for sources of PCK (see Appendix E for complete open code book).

Table 4.7

Most Frequently Cited Open Codes for Sources of PCK

Code	Definition	Frequency
TB	Use of course **t**ext**b**ook	17
INT	General search of **int**ernet sites	11
VID	Use of online **vid**eos about topics	10
MED	Use of online **med**ical sites	4
REF	Use of **ref**erence books other that the course textbook	4

Note: Appendix E provides the complete open code book for sources of PCK.

The codes INT, MED, and VID referred to online websites typically used to get ideas for either improving content knowledge or pedagogical knowledge, and together were coded most often in the data with 25 instances. David best illustrated his use of internet searches (INT coded) to improve his pedagogical knowledge in his comment below.

We have the internet; we can search for ideas about lab activities and find pictures or videos, I mean just infinite number of things so like just doing research like that and finding other ideas that maybe someone else is coming up, come up with and you know *kind of refining them, figuring out if I can use them for my own purposes* (David, video-stimulated interview).

Similarly, Vera described her use of online sources (INT code) to improve her pedagogical knowledge, stating, "*there are so many different sites, like Bozeman Science and Crash Course and Kahn Academy, that do that in a very short period of time. So, sometimes I'll look at those and say "Ok, how did they present this? Is that more palatable than the textbook?"* (Vera, preliminary background interview). David and Vera also emphasized their use of online medical sites (MED code) to clarify their understanding of scientific concepts. Vera best exemplified this use of online medical sources in the following remarks,

> *I looked up a lot of the terminology because I wasn't familiar with it. So, just different medical sites because, you know, you could have a whole course just talking about the brain. And, a lot of the terms you might know the root or the suffix or the prefix, and you kind of have an idea of what it means, but I'm like, 'ok, let's make sure.' So, that when I'm teaching it to them . . . giving them the correct definition.* (Vera, weak pre-observation interview).

Sheila emphasized her use of online videos (VID code) for ideas to improve her instructional methods, noting, "*I've watched a lot of YouTube videos with professors teaching topics. I really tried to prepare very well for this* [topic] *since I know it's a weak spot*" (Sheila, weak pre-observation interview).

Additionally, the codes TB and REF described publisher-developed materials, and taken together were coded 21 times in the data. All participants primarily used the course textbook and related publisher-developed materials to design their overall instructional presentations. Jerry and David used the publisher-developed powerpoints as a starting point, and then edited them for the content they deemed most important. Jerry explained that he gets his ideas for content material "*usually from the textbook and the associated material*" (Jerry, video-stimulated interview). David further elaborated, "*here's the textbook I'm supposed to use; here's the chapters we're supposed to get through*" (David, video-stimulated interview). Additionally, Sheila and Vera used the textbook to guide the development of their notes presented on the white board during their lectures. Sheila explained, "*I follow the textbook and the information on that because I want make that – that's what they're going to be tested on, you know, the information they're going to be reading about in the text so I stick to those topics*" (Sheila, weak pre-observation interview). Vera indicated that she gives her students a copy of the notes she created based on the textbook and then presented during the class lecture. She stated, "*I always give my class notes that I transcribed when I read the book because it was written by nurses; I'm not a nurse. And, I teach it as a biology class, so in the notes I try to emphasize what I think's important and what we're going to talk about*" (Vera, strong pre-observation interview).

Participants also indicated other sources of PCK such as trial and error (17 instances), modeling their teaching behaviors, and observation of other instructors without modeling (8 instances). When asked how they learned to teach their content topics, common responses related to trial and error included "*on the seat of my pants*" (Jerry, video-stimulated interview), "*by teaching it*" (David, strong pre-observation interview), and "*past experience of things that work and things that don't work*" (Sheila, video-stimulated interview. Additionally, Jerry emphasized how he modeled his teaching methods after his own college instructors in his comment below.

> *So, this is actually part of my own learning because most of us learn through modeling. And, I have never been modeled anything other than a traditional lecture. I have never*

seen another way of teaching . . . . So, my philosophy is stay with that but incorporate some of the new things like internet, but have that be the core – here's the information you need to know, and it's up to you as the student to . . . figure it out (Jerry, preliminary background interview).

And, Sheila described how her observation of other instructors influenced her instructional strategies, stating, "*watching other instructors and seeing what they do; getting ideas from them . . . I just based it on what other teachers have done, and just sort of tweaked it on what works for me*" (Sheila, weak pre-observation interview).

Although, the participants described several different sources they used to increase either their content knowledge or pedagogical knowledge, the two sources of PCK used most often were online sources and publisher-developed sources.

Theme 2: Acute interest in appropriate professional development designed to improve overall PCK. All participants expressed genuine interest in potential professional development activities designed to help them improve their instructional strategies, thus, improving their overall PCK. David exemplified his need for professional development in the following explanation.

I don't totally understand the whole teaching methods thing. I mean I get that there are different ways that you can teach things but like the whole idea of studying teaching methods is foreign to me . . . I would say I have a greater appreciation for it than I, than I used to. I think when I got out I felt like, I probably felt like, boy I learned, I learned a lot of stuff at getting my PhD, I'm ready to teach, you know. And then you start teaching, and then you find like oh this isn't so easy. And, so you know, the idea of like how to learn how to say things in a way that people understand or remember or be interested in *what you're saying, there's definitely something to it. I never took an education class like that, ever, you know, not as an undergrad, not in graduate school, and I can certainly see a point for doing it* (David, video-simulated interview).

Similarly, Sheila described her interest in developing instructional strategies to increase student engagement, noting,

> *Classroom or student engagement is a big issue, and not for everyone, I have a lot of really good students that are tuned in and ask some good questions but then you have those in the back that are on their phones and yeah doing whatever and it's like, how* do I *reach those particular students? Is it even possible to reach those students because they've already checked out? So what could I do differently to engage them so I try to work around all learning types, but I might not hit them all because, you know maybe I should incorporate some type of learning tool to understand what the learning types are* (Sheila, video-stimulated interview).

Additionally, Jerry described his need for professional development, stating,

> *Never having had proper training in teaching methodology, I welcome the professional development because content wise, not too many people can rival me content wise. But I realize that I don't know what all the teaching methods are, right, so the professional development is important . . . . so, I have the content, finding different ways to deliver the content is important for me to know* (Jerry, video-stimulated interview).

And, Vera summarized her positive experiences with professional development had influenced her overall PCK in her comment below.

> *Going to the teacher, community college teacher association meetings that we went to, that was really helpful. Some people had some really creative ways to try and get their*

students to learn. Things that I would never have thought of . . . because I was not an education person, I was a science person, and I just happened to end up in science education. It gave me a different perspective because I'd only ever taken one education class. So, it gave me a different perspective on how people that actually trained to be science teachers thought through processes (Vera, video-stimulated interview).

Although participants are interested in relevant professional development opportunities, they described an overwhelming lack of time to either seek out professional development or to implement ideas they learned during professional development. For example, David described his unease at attending professional development due to his demanding work load, commenting,

> *I feel like with the, with the level of, the teaching load that we have here for me to say like, 'okay I'm going to take time out to go to a meeting and maybe even miss class,' to me it's not something I feel very comfortable with cause I feel like I've got a lot of pressure to keep things going in my classroom; and every time I step out, whether it's me being sick or a snow day or going to a conference, it's like it's more work for me to not be here then to be here. And my workload is already high enough; and, so you know, do I want to justify that. Do I want to do that?* (David, video-stimulated interview)

Similarly, Jerry described how his teaching load impeded his ability to implement an exciting new technique in his classroom that he had learned about at a chemistry conference, explaining,

> *At that conference, somebody, they had this great idea, and but it seemed really involved and I asked them like how can I do this when I have like 4 or 5 classes? And he's like, what do you mean? He's like how many contact hours? Last semester I had 27. He's like, you can't. He's like I have two classes every semester, this is hundreds of hours like set-up and then it works really well but, you know so, to have the, I mean it's one thing to*

have the professional development but again, you have to have some breathing room to implement it (Jerry, video-stimulated interview).

Furthermore, participants also indicated they felt the college administration did not support their professional development needs. Jerry emphasized the little to no amount of compensation provided for traveling to professional development activities as well as the teaching load issue in his comment, "*So, more access to travel to, even local conferences . . . It would be nice to have some, that kind of professional* [development], *in house, but if not, then at least be able to go to them. And then yeah just, you know, the contact hours need to be adjusted*" (Jerry, video-stimulated interview). Sheila indicated that her college did offer professional development, but that the topics were irrelevant or scheduled at inconvenient times in her statement below.

> *I mean like they put these so-called professional development days but most of the topics are like why are you putting that in? And I kind of question the leaders of those types of professional development. I'm sorry, I'm just speaking frankly. And it's in the middle of a day when you've got classes going on, so honestly, I can't make any of those. Because you know I'm going to a different county that day, coming back, and I have a three-hour class that night. I just, I just can't make it to any of them.* (Sheila, video-stimulated interview).

Similarly, David elaborated on the irrelevant, mandatory professional development provided by his college, stating,

> *I think I'm told I'm supposed to do it. There're events that are organized that I say, I'm told I'm supposed to attend that will do such things and most of the time I don't think they're very relevant to anything I do. But it counts, so it checks a box for them. So it*

gets put on my list, but you know for any professional development I'll put other things on there too that probably are unrelated. So like when I say I'll go off and read things. I'll go to, sometimes I find out about a seminar at another university, and I'll go see it. And you now it's about physiology or genetics or medicine or whatever, just maybe it's something I think just sounds cool. And then, but it's like, 'ah that's really neat; I learned something new.' To me that's professional development for me, and I put it on my list. I don't care whether anybody else likes it or not, but I think that's valuable. (David, video-stimulated interview).

Clearly, all participants are interested in participating in relevant professional development that targets both increasing their own content knowledge as well as various instructional strategies to increase student engagement and learning. However, large teaching loads have hindered their access to professional development and implementation of the strategies learned in these sessions.

Summary

In this chapter, relevant data was presented to support multiple themes generated for each research question. First, three themes related to the PCK characteristics of community college biology instructors were presented. The first theme described how the participants' preferred orientations conflicted with their actual orientations. Next, the second theme emphasized the weak connections among the PCK components which indicated these participants had less sophisticated overall PCK. The data also revealed a third theme that time exerted an external pressure on PCK by limiting potential instructional strategies.

Next, with respect to the relationship between content knowledge and PCK in community college biology instructors, the findings indicated two important features. First, content knowledge did not significantly affect PCK based on a comparison of PCK maps between strong and weak content topics, the equal number of PCK episodes between strong and weak content, and the similar quality of PCK interactions between strong and weak content. Second, content knowledge did not impact individual components of PCK. In particular, KSU, KISR, and KA components were not affected by the difference in content knowledge.

Finally, these community college biology instructors relied heavily on online and publisher-developed sources in planning and enacting lessons that in turn greatly impacted their KISR. Also, these community college biology instructors demonstrated significant interest in professional development designed improve their instructional strategies, which in turn would improve their overall PCK.

CHAPTER 5

DISCUSSION

The purposes of this qualitative study are: 1) to describe the characteristics of PCK demonstrated by community college biology instructors; 2) to understand how content knowledge influences PCK in community college biology instructors; and, 3) to describe the sources community college biology instructors use to develop their PCK.

In this chapter, the results related to each research question are discussed. First, key PCK characteristics found in all four participants are examined, including teacher-centered orientations, student responsibility, and limited applications of assessment. Secondly, findings related to the relationship between content knowledge and PCK are explored. Next, the sources of PCK development in these participants are discussed. Then, limitations of the study are presented followed by implications for scholarship and practice.

Characteristics of PCK in Community College Biology Instructors

In this study, all participants described student-centered learning activities as the best type of instructional strategy for learning science; however, they all demonstrated primarily didactic orientations in the classroom with teacher-centered lecture as the primary mode of knowledge transmission (Magnusson et al., 1999). These participants reported they have difficulty seeing ways in which to implement student-centered approaches in their biology classes because of a time pressure to cover all the material before a test. Bennett and Park (2011) reported a similar finding regarding time when their case study teacher described his reluctance to incorporate student-centered activities because of the amount of time investment required in those types of classroom practices.

Furthermore, many of the participants in this study discussed their choice of teacher-centered lectures as being a product of their own post-secondary educational experiences. In essence, they were modeling their teaching behaviors based on the teaching behaviors of the instructors they had during their undergraduate and graduate education. Hence, they were perpetuating the teacher-centered lecture model of information delivery. These results are not uncommon in K-12 education research. Yilmaz-Tüzün and Topcu (2010) identified a similar conflict between teacher beliefs and their K-12 science classroom practice. Furthermore, Bennett and Park (2011) found that teachers' own experiences as students strongly influenced their teaching practices. Similar results have been extensively reported in K-12 research by multiple researchers over several decades, including Lortie (1975), Grossman (1991), and Eick and Reed (2002). Bennett and Park's (2011) conclusion nicely summarized this idea, stating, "it is natural for teachers to attempt to reproduce their classroom experiences (unless they were negative) as opposed to implementing a style of teaching that they have never seen or been exposed to before" (p. 82).

Additionally, this study also revealed the limited integration between only two or three PCK components indicative of less sophisticated PCK in these participants. Previous research by Park and Chen (2012) concluded that the quality of PCK demonstrated by teachers was a result the synergism among individual components rather than just a sum of those of components. Similar results from this study indicated these participants demonstrated very superficial understandings of each individual PCK component, which may have contributed to the overall limited reciprocity among those components, resulting in less sophisticated PCK. More recently, Cain and Graves (2018) also found that both strong content knowledge and strong pedagogical knowledge were important in developing stronger, more sophisticated PCK in biology teachers. Given the lack of pedagogical training in community college biology instructors, their severely limited insights regarding each individual component, in particular their lack of pedagogical knowledge, may have contributed to the less sophisticated integration of these components indicated by their weaker overall PCK.

In this study, all participants expressed that the student is responsible for their own learning. This orientation implies that teaching can occur even if learning does not. These participants viewed teaching as a provision of information and resources, while it is up to the student to use these resources to learn the information for themselves. The concept of student responsibility in their own learning process is commonly discussed in the research literature across grade levels. For example, Corno (1992) described ways that primary grade level teachers "might encourage students to take responsibility for their own learning and performance in school" (p. 69), indicating that it is important for students from very early ages to engage with the content on their own as a way to develop their role as students and create this sense of responsibility. Similarly, Hsu, Roth, and Mazumder (2009) offered multiple opportunities for individual practice in high school science courses in order to develop students' autonomy for their own learning, thereby cultivating their sense of responsibility. More recently, this correlation between learning and student effort was also identified by Jena and Chakraborty (2018) in their study of 100 university students, which included 40 science education students. They found college students believed that their learning depended on either their effort or their ability. It is not hard to imagine that science education students who believed their own learning is dependent on their effort in a course may become instructors who believe the same thing about their future students.

Another key finding in this study revealed that these participants viewed assessment solely as a measurement tool of students' learning rather than a diagnostic tool to identify deficiencies in students' understanding. They relied heavily on summative measures at a single point in time to measure students' learning about the science content. They also demonstrated limited use of formative measures which would help to reveal students' misconceptions and provide opportunities to address them prior to the summative examination of their understanding. Goubeaud (2010) reported similar results in a large-scale study of post-secondary assessment practices across science disciplines. The study concluded various summative measures were primarily implemented, while formative assessments designed to promote students' understandings of science were much less utilized (Goubeaud, 2010). Webber (2012) provided a possible explanation for this heavy reliance on summative assessment in community college courses related to higher teaching loads hindering the commitment of these instructors to develop more student-centered assessment strategies. The results from this study supported the findings by Goubeaud (2010) and Webber (2012) because these community college biology instructors described a pressure regarding the limited amount of time to cover content material as well as demonstrated limited formative assessment practices.

Taken together, these participants' beliefs of how a college science class should look, the roles of science teachers and learners, and how assessment is used have all contributed to the teacher-centered classroom practices observed in these four community college biology instructors. While these teaching orientations may be difficult to change given the prior learning and teaching experiences of these instructors, they have all expressed strong interest in changing their teaching styles to more student-centered learning activities. Recently, Sickel and Friedrichsen's (2018) concluded that "a constructivist orientation does not exclude all forms of direct instruction, but rather highlights the importance of providing experiences for students to construct knowledge, using formative assessment to inform instruction, and facilitating meaningful inquiry experiences" (p. 62). Similarly, this study uncovered the necessity of these community college instructors to develop more student-centered instructional strategies and different ways of assessment to gauge students' understandings. Therefore, Sickel and Fridrichsen's (2018) deduction coupled with the findings in this study strongly support the notion that professional development programs designed for community college biology instructors should focus on development of the individual KISR, KSU, and KA components of PCK as ways to develop more sophisticated PCK in these instructors.

Relationship Between CK and PCK in Community College Biology Instructors

Recent research in K-12 science teachers continues to find that content knowledge is a pre-requisite for PCK development (Friedrichsen et al., 2009; Kanter & Konstantopoulos, 2010; Luft, et al., 2011; Park & Oliver, 2008a; Park & Oliver, 2008b; Şen, Öztekin, & Demirdöğen, 2018). However, Lee et al. (2007) found that strong content knowledge does not necessarily lead to PCK development in secondary science teachers. Similar to Lee et al.'s (2007) findings, the results from this study found that content knowledge in these community college biology instructors did not significantly affect their PCK. Additionally, this study also found each individual component of PCK in all participants looked similar regardless of their type of content knowledge, which may have also contributed to their overall less sophisticated PCK for both strong and weak content. An important distinction to remember here is the difference in pedagogical training between K-12 and post-secondary instructors. Since community college instructors need only a master's degree in their content area to teach their subject matter and many do not have any formal pedagogical training, their overall weaker, less sophisticated PCK may be connected to their lack of pedagogical knowledge. Therefore, developing better pedagogical knowledge would lead to the development of more sophisticated PCK.

Given the time demands of community college biology instructors, action research may "provide a context for making purposeful change" (Krajewski & Schwartz, 2014, p. 562). The reflective component of action research aligns with van Driel and Berry's (2012) assertions that reflection is an important part of PCK development and professional learning communities are useful "in helping teachers to explicate and discuss key notions of teaching and learning a specific topic" (p. 27). Additionally, Capobianco and Feldman (2010) found action research positively correlated to improvements in instructional practice. Krajewski and Schwartz (2014) used action research as a way to develop PCK related to nature of science (NOS) in one community college biology instructor. This instructor reflected on her experiences during the action research study, stating,

> Action research provided me with the opportunity to devise an intentional and systematic plan in order to assist in developing an understanding as to how I could come to develop PCK for NOS. This year long reflective action research experience has not only changed how I teach science, it has altered how I view science education (Krajewski & Schwartz, 2014, p. 562-563).

Clearly, action research was successful in improving PCK related to NOS for this community college biology instructor; therefore, it may also be a successful method for other post-secondary biology instructors to develop more sophisticated PCK by improving instructional strategies for additional biology topics.

Sources Used to Develop PCK in Community College Biology Instructors

Review of the research literature yielded many potential sources of PCK development in K-12 science teachers and fewer sources in post-secondary science instructors. The majority of recent studies in K-12 science teachers have focused on the effects of teaching experience, professional development, mentorship, and content knowledge on PCK development (Burton, 2013; Hanuscin et al. 2011; Jang, 2011; Jang et al., 2013; Kanter & Konstantopoulos, 2010; Khourey-Bowers & Fenk, 2009; McNeill & Knight, 2013; See, 2014; van Driel & Berry, 2012). Recent research studies of PCK in post-secondary science instructors identified professional development, teaching experience, reflection, and contact with cooperating teachers as sources of PCK development (Dotger, 2011; Goodnough, 2006; Jang, 2011; Jang et al., 2013).

This research study expanded sources of PCK development in post-secondary science instructors to include strong utilization of online sources and publisher-developed materials. These two sources primarily guided the instructional design of content presentation for the participants in this study. Unlike K-12, there is no common science curriculum that is implemented throughout the community college system. It is widely accepted that community college science curricula are primarily designed and implemented by individual instructors for each science course usually based on the science content developed by the publisher of the course textbook. For example, Kenyon, Onorato, Gottesman, Hoque, and Hoskins (2016) investigated the impact of innovative CREATE pedagogy as an alternative to "textbook-prescribed curriculum" (p. 2) in community college science classrooms. They concluded that these two-year science instructors were able to teach science more effectively using the CREATE pedagogy because their community college science students demonstrated improved abilities in both designing experiments and thinking critically (Kenyon et al., 2016). In addition to the primarily textbook-driven course design, the results from this study showed these instructors are also using general online searches to look for potential online, classroom, or laboratory activities and current research or news items that complement the material in the course textbook.

van Driel and Berry (2012) asserted that "PCK development is a complex process that is highly specific to the context, situation, and person" (p. 27). Similarly, Rozenszajn and Yarden (2014) argued that professional development programs for PCK expansion must be designed to address the unique PCK held by individual instructors if meaningful and effective professional develop is to occur. The results of this study implied that community college biology instructors' reliance on only two primary sources for PCK development may be a contributing factor of their underdeveloped PCK. Therefore, making them aware of additional sources of PCK development, such as science education programs or classes and professional development opportunities designed to address their unique needs as community college instructors, may encourage them to increase their participation in more collaborative sources of PCK development.

Limitations of the Study

Several limitations were identified in this study due to the complex nature of examining the PCK of an instructor. First, in qualitative research, the researcher was the primary agent used in analysis of the data. Hence, the interpretations of this data may vary from other researchers' understandings conducting similar studies. Potential researcher bias was addressed by triangulating the results from multiple sources of data, including interviews, observations, field notes, and classroom artifacts. Additionally, the data analysis process was discussed using peer debriefing and interrater checks (Lincoln & Guba, 1985; Shenton, 2004; Silverman, 2001).

Second, PCK cannot be directly measured. It has to be inferred through interviews and observations with the instructors. It is important to note that the instructors may not be fully aware of their own ideas about pedagogical issues, or they may not be able to fully explain them to the researcher (Bennett & Park, 2011; Leatham, 2006; Pajares, 1992). Therefore, this study cannot guarantee complete infallibility in the assessment of the pedagogical ideas presented, even though multiple methods were implemented to mitigate these effects as much as possible. These methods included using multiple types of data collected over a prolonged period of time for each participant as well as triangulation of the multiple sources and peer debriefs (Lincoln & Guba, 1985; Shenton, 2004; Silverman, 2001).

Finally, the researcher cannot generalize the findings to all community college biology instructors due to the nature of the basic qualitative research methods applied to a small number of participants. However, the researcher aimed to provide enough thick, rich description about the educational significance of these four participants that readers will be able to transfer these findings to similar contexts involving the impact of characteristics and sources of PCK development on the practice in community college biology classrooms (Lincoln & Guba, 1985; Shenton, 2004; Silverman, 2001).

Implications for Scholarship

The current research literature base for PCK in post-secondary instructors is limited, especially for two-year biology instructors. This study contributed to deficiencies in the research base by describing characteristics of PCK, exploring the relationship between content knowledge and PCK, and identifying sources of PCK in biology instructors at community colleges. This research study identified strong teacher-centered orientations in this cohort, which may be difficult to change given the prior learning and teaching experiences of these instructors.

Additionally, this study showed that content knowledge did not impact PCK and identified a strong interest for effective professional development opportunities in this cohort. This study was unique as it is one of the first studies to explore PCK in community college biology instructors. Therefore, it can be used to guide the development of many future research studies, primarily in the area of professional development in the unique context of community college science courses.

Girvan, Conneely, and Tangney (2016) used experiential learning in the design of their professional development model as a way to make significant pedagogical changes. This design provided teachers with opportunities to experience new pedagogical approaches as a learner first, and then, they adapted and implemented those strategies in their own classrooms. Afterwards, these teachers were given time to reflect on their experiences with these new instructional strategies and this type of professional development process influenced their beliefs, which resulted in substantial changes in their classroom practice. Given the strong interest of the participants in this study to incorporate more student-centered activities into their classrooms, this type of experiential professional development model may be ideal to increase their KISR component, potentially resulting in more sophisticated PCK.

Next, since content knowledge was not correlated to their unsophisticated PCK, it was proposed that their lack of pedagogical knowledge may be linked to their low levels of PCK. Future research studies could address multiple aspects of this relationship between the lack of pedagogical knowledge and PCK development in post-secondary instructors. For example, does increased pedagogical knowledge, in fact, positively correlate to the development of more sophisticated PCK? If so, what are the best practices for addressing the limited pedagogical training for post-secondary science instructors, especially at the community college? Does more sophisticated PCK in post-secondary instructors lead to higher student outcomes similar to the trends reported in K-12 research? If so, does more sophisticated PCK positively correlate with higher student success rates in science courses at community colleges? These are just a few potential research questions related to the relationship between improved pedagogical knowledge and PCK in community college science instructors.

Finally, this research study identified two primary sources of PCK development, including strong utilization of online sources and heavy reliance on publisher-developed materials. Additionally, the results revealed an acute interest in professional development by these four community college biology instructors. Based on these participants' discussions, they indicated a preference for professional development designed to address more student-centered instructional strategies to increase students' understanding of scientific concepts. They also indicated a desire for opportunities to practice these strategies before implementation in the classroom and have time for reflection to improve upon these strategies. Therefore, future research studies should explore what components should be incorporated into professional development sessions that would effectively increase pedagogical knowledge and allow additional opportunities for community college science instructors to develop more sophisticated PCK. In other words, what constitutes "effective" professional development for community college science instructors? For example, should professional development programs provide new information on instructional strategies, planning time for possible implementation, discussion opportunities about implementation, reflection time after implementation, or some combination of all of these components?

Future research could examine the design and layout of professional development models that best accommodate the needs of community college instructors. For instance, given the heavy teaching demands of community college science instructors, what type of time commitment would effective professional development require? Should these sessions be designed as shorter meetings that continue to meet multiple times throughout the school year or as single workshops lasting one or two days? Ultimately, future research needs to consider both the needs and high work load demands of community college science instructors when developing appropriate professional development opportunities that target community college faculty.

Implications for Practice

This study contributed to the limited research base by exploring and describing the characteristics and sources of PCK for biology faculty at community colleges. The results from this study showed the strong interest of community college science faculty for participating in relevant professional development designed to improve instructional strategies for science content. Therefore, effective professional development programs should be designed to encourage the development and integration of PCK, specifically for biology courses and more broadly for STEM courses, in the context of community colleges. Additionally, the results from this study can help improve science education programs by providing courses to enhance PCK of post-secondary science instructors, specifically targeting the unique context of community colleges. Based on the findings in this study, science education programs should be designed to develop pedagogical knowledge of community college science instructors, specifically providing opportunities to design, implement, and reflect on new instructional strategies for science content.

Recently, van Driel and Berry (2012) argued that professional development programs designed to improve PCK for science teachers must be designed based on constructivist theories unique to the context of the teacher instead of behavioral approaches. Furthermore, both van Driel and Berry (2012) and Rozenszajn and Yarden (2014) asserted that professional development programs designed to develop PCK must closely align with their unique professional practices, including the implementation of new instructional strategies and learning materials specific to their experiences and needs. Additionally, Rozenszajn and Yarden (2014) further contended that biology and science education courses would also significantly benefit the development of PCK in science teachers. Results from this study supported all of these assertions by highlighting the desire in this cohort for more integration of student-centered activities which can be addressed during professional development designed to specifically address the needs of these community college biology instructors in developing better pedagogical knowledge and more sophisticated PCK.

In conjunction with innovative instructional strategies, professional development designed to target PCK development should also incorporate opportunities to develop mentor relationships between experienced and novice community college instructors as well as among these two-year science instructors and science education faculty. In this study, one participant explicitly explained his belief that he would have benefited from the experiences of more seasoned community college biology instructors early in his career. Furthermore, this participant felt that his own experiences gained from 20 years of teaching would be beneficial to novice community college biology instructors. The results from this study situated in the context of post-secondary education at the community college are supported by similar findings in K-12 research describing the role of mentors in PCK development of science teachers.

Early research by Clermont et al. (1994) highlighted that “pedagogical content knowledge growth without a mentor is often gained slowly through trials and errors, reteaching efforts, and gradual successes" (p. 438). Since then, multiple research studies have shown the significant impact of mentorship on PCK in K-12 science teachers (Appleton, 2008; Hanuscin et al., 2011; Peers et al., 2003; See, 2014; van Driel et al., 2002). It is important to note that research related to mentorship in post-secondary science disciplines is limited; therefore, the results presented here is one of the first research studies to identify mentorship as a possible source of PCK development in post-secondary community college instructors.

Based on prior research in K-12 science teachers and the results of this study, mentor relationships should be encouraged within community colleges by pairing new faculty with more experienced faculty to promote the sharing of information so new faculty may avoid pitfalls experienced by more seasoned faculty. Additionally, given the potential lack of pedagogical training in many community college science instructors, it may also be useful for community colleges to create mentor relationships with local science education programs and faculty to provide support to community college science instructors in the development of both their pedagogical knowledge and PCK. The development of positive mentorships could support and encourage community college faculty to maintain newly developed PCK, as well as persist in continuous practices of developing more sophisticated PCK throughout their teaching careers.

Finally, while community college science instructors demonstrated strong interest in professional development, key findings from this study indicated that the heavier teaching loads of community college faculty served as a road block for their participation in such programs. It is important to understand the time demands of teaching course loads as high as twenty-one contact hours can be detrimental to both participation in professional development as well as the implementation of new strategies learned in professional development. Additionally, both professional development and science education programs should take into consideration the varied teaching hours of community college instructors and offer their activities during daytime and evening hours and consider an online format as well. Furthermore, the results in this study indicated that while community college faculty may be able to find time to attend professional development sessions, the professional development is ineffective and wasted if they do not have sufficient time to plan and implement in their classrooms what they have learned in these sessions.

Smith (2007) reported similar challenges to participation in professional development for both the full-time and part-time faculty a community college located in Massachusetts. Smith (2007) identified rigorous workloads (including teaching duties, advising, and community service), conflicts with teaching schedules, little reimbursement for travel issues (mileage, meals, accommodations), little compensation for time spent at the conference as impediments to professional development for full-time community college faculty. Smith (2007) also identified two issues specific to part-time community college faculty, including conflicting schedules with full-time positions and simply being unaware of professional development opportunities. Notably, the participants in this study are located in a different community college system from the one described by Smith (2007). Given the similarities described in this study and Smith's (2007) study, it appears that barriers to professional development faced by community college instructors are related to the general context of the community college rather than one specific institution. The results in this study also supported Smith's (2007) conclusions that community college faculty are eager to participate in professional development despite the challenges they face in the unique context of community college institutions.

Furthermore, the Center for Community College Student Engagement (CCCSE) (2010) has argued that all community college faculty must have opportunities to participate in professional development activities in order to increase their instructional effectiveness. They concluded that numerous research initiatives have identified the best practices for teaching and learning; however, community college instructors must be provided with the necessary opportunities to learn about these best practices for instruction and implement those strategies in their own classrooms. Similarly, research findings in this study highlighted important issues related to professional development that community college administration must consider if they want to promote a culture of continuous improvement within these institutions. One key consideration by community college administration should be limiting workload expectations of full-time faculty in order to provide more time for participation in professional development and planning for the implementation of new instructional strategies. For example, reducing administrative duties such as advising, committee involvement, and community service requirements may provide the necessary additional time to attend professional development, plan new strategies, and implement these strategies. Additionally, community college administration may consider lowering the maximum number of required teaching contact hours and/or lowering the maximum number of students per class section. With additional time to plan and/or fewer students to attend to, community college instructors would be more likely to incorporate new instructional strategies, which in turn could improve their overall PCK and potentially increase students' completion rates in science courses. Another important consideration is compensation for participation in professional development activities. For example, community college administrations should consider providing various types of compensation, such as paid conference registration, paid leave and travel expenses, which may encourage and support faculty in pursuing professional development opportunities. Additionally, community colleges should also investigate potential sources of funding offered by federal, state, and local organizations to help assist with the costs of faculty participation in professional development programs. In order to develop a culture of continuous improvement, it is important that both faculty and administration in community colleges work together to find reasonable ways to support participation in professional development as well as implementation of strategies gained in these activities, which may in turn positively affect both students' success and completion rates.

Summary

In this chapter, relevant results pertaining to each research question were discussed. First, several common PCK characteristics observed in all four participants were presented, including teacher-centered orientations, student responsibility, and limited applications of assessment. These participants' beliefs of about how college science classrooms should look, the roles of teachers and learners, and the uses of assessment primarily contributed to the teacher-centered classroom practices observed in these four community college biology instructors.

Second, key results related to the relationship between content knowledge and PCK were examined. The participants demonstrated similar PCK between their strong and weak content areas, which suggested that content knowledge alone is not sufficient for PCK development. Additionally, since many community college biology instructors do not have any formal pedagogical training, their less sophisticated PCK may be connected to their lack of pedagogical knowledge.

Next, the primary sources of PCK development for these participants were presented. This study identified online and publisher-developed materials as sources of PCK development in post-secondary science instructors. These sources were used to design the overall instruction in biology courses taught by the participants in this study.

Finally, limitations, implications for scholarship, and implications for practice were discussed. Limitations focused on the nature of qualitative research and complexity of PCK. Implications for scholarship and practice focused on the design of relevant professional development and science education programs targeting the needs of biology instructors in the context of community colleges.

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APPENDICES

Appendix A

North Carolina State University

INFORMED CONSENT FORM for RESEARCH

<u>Title of Study:</u> The Characteristics and Development of Pedagogical Content Knowledge (PCK) in Community College Biology Instructors

<u>Principal Investigator</u>: Brandy Bowling

<u>Faculty Sponsor:</u> Dr. Soonhye Park

<u>What are some general things you should know about research studies?</u>

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue.

You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

<u>What is the purpose of this study?</u>

The purposes of this study are: (1) describe the characteristics of pedagogical content knowledge (PCK); (2) characterize the development of PCK; and (3) understand how content knowledge (CK) influences PCK in community college biology instructors.

<u>What will happen if you take part in the study?</u>

If you agree to participate in this study, you will be asked to participate in one hour-long preliminary background interview, two 15-minute pre-unit observation interviews, two 15-minute post-unit observation interviews, and two hour-long video-stimulated interviews. All interviews will be audio recorded. You will also be asked to have video recordings completed for two different units in your selected biology courses.

Risks and Benefits

There are minimal risks associated with participation in this research. There are no direct benefits to your participation in the research. The indirect benefits may include improved PCK in science teaching, improved student learning in biology courses, an increase in completion of STEM-related degrees, and more potential candidates for STEM-related careers to improve the United States' global competitiveness in STEM areas.

Confidentiality

The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely in locked offices and password protected computer files. No reference will be made in oral or written reports which could link you to the study.

Compensation

You will not receive any compensation for participating in this study.

What if you have questions about this study?

If you have questions at any time about the study or the procedures, you may contact the Principal Investigator, Brandy Bowling, at PO Box 72672, Durham, NC 27722, or email at blbowlin@ncsu.edu or telephone number 919-819-4376.

What if you have questions about your rights as a research participant?

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator at dapaxton@ncsu.edu or by phone at 1-919-515-4514.

Consent to Participate in this Research Study

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Participant Signature____ Date ______________

Investigator signature____ Date ______________

Appendix B

COMPLETE RESEARCH QUESTION DEVELOPMENT TABLE

Research Question 1.

What are the characteristics of PCK in community college biology instructors?

What do I need to know?	How can I know? Possible Data Sources	Major Interview Questions
What are some examples of PCK demonstrated by them in class?	Video recordings; video-stimulated interview; observations; field notes; documents/artifacts	1. What are the difficulties or limitations connected with teaching this topic? 2. Why did you use these (insert strategies) to teach this topic? 3. Describe how you assessed if students learned what you intended for (this topic). 4. Are there other ways that you might know what your students learned about (this topic)? 5. Why did you decide to use this particular assessment strategy? 6. From your video and/or lesson plan, it appears that you chose to start the class (continue class; end the class) with (this strategy: warm-up, lecture, experiment, investigation, etc.). Why did you choose to start (continue; end) this way? 7. I noticed that you used this (picture, graph, equation, analogy, etc.). Why did you use this at this point? How do you think this representation helps students learn about (this topic)?
What PCK components do they integrate into their lessons?	Preliminary Background interviews; video-stimulated interviews	1. What were your purposes and goals for this lesson? 2. How did you decide on these purposes and goals? 3. What do you intend for students to learn about this topic? 4. Why is it important for students to know this? 5. How did that science fit into the bigger picture of what students learn in this class? 6. How does (this topic) fit into the "big picture" of what students learn about science in previous science courses and later science courses?

Major Interview Questions continued

7. Please explain any curricular programs you use for teaching this topic.
8. Tell me about the students in this class, in terms of science.
9. Tell me more about your students' attitudes about science?
10. Tell me about your students' science abilities.
11. What do you think the students already knew about (this topic)?
12. Why do you think that they may know that?
13. Where do you think they may have learned this already?
14. Did you expect students to have difficulty with anything that you had planned and presented?
15. What parts of this did you think would be most difficult for them?
16. How did you find out these parts were hard for them?
17. Why did you think they would have difficulty with that?
18. What did you plan to assess during your instruction? Why do you think it is important to assess this?
19. Describe how you assessed if students learned what you intended for (this topic).
20. Are there other ways that you might know what your students learned about (this topic)?
21. What did you do with the information you gained from the assessment?
22. What challenges did you see as you assessed your students?
23. Did the lesson achieve the purpose you intended? Why do you think that? 24. How did your curriculum materials support or hinder you in implementing your lesson plans?
25. Why did you decide to use (this representation) for this topic?
26. How did the way you used (this representation or strategy) improve the lesson, if at all?

	<u>Major Interview Questions continued</u> 27. What changes, if any, would you make if you were to use (this representation or strategy) again? 28. In what other topics could (this representation) be used? 29. How could you use (this representation or strategy) in a different way? 30. What do you think the student was thinking (here in video)? Why do you think the student was having difficulty at that point? 31. What misconceptions do students typically have when completing this lesson? 32. What do student difficulties with this topic typically look like? How do you know?

Research Question 2.

How do community college biology instructors' content knowledge relate to their PCK?

What do I need to know?	How can I know?	
	Possible Data Sources	Major Interview Questions
How did they become experts in their content areas?	Preliminary Background Interviews	1. Describe your educational background (degrees earned). 2. Describe your professional teaching experiences (years; grade levels; courses). 3. Describe your professional experiences unrelated to teaching. 4. What is your teaching philosophy? 5. What is your purpose in science teaching? 6. How do you prefer to teach science? 8. Think of yourself as a science learner; how do you best learn science concepts? 9. What do you think is the best way(s) to engage students in learning about science? 10. How comfortable are you with the subject matter for this topic? Where did you learn about this topic in your prior coursework or experiences? 11. Consider a typical day of teaching science. What is the teacher's role in a typical science lesson? What is the students' role in a typical science lesson? 12. How do you think students learn science best? What about this particular group of students? Why do you think that?

What are their sources of PCK?	Described below in Research Question 3.	Described below in Research Question 3.
What PCK components do they integrate into their lessons?	Previously described Research Question 1.	Previously described in Research Question 1.

Research Question 3.

What sources do community college biology instructors use to develop their PCK?

What do I need to know?	How can I know?	
	Possible Data Sources	Major Interview Questions
What are their sources of PCK?	Video-stimulated Interviews; Observations; Field Notes; documents/artifacts	1. How did you learn to teach this topic? 2. Where did you get your ideas for teaching this topic? 3. Why did you use these (insert strategies) to teach this topic? 4. Tell me about the materials you prepared. Where did these materials come from? What modifications did you make to existing materials? 5. How do you think these materials helped or hindered achieving the purposes of your lesson? 6. Where did you learn how to (start; continue; end) this lesson in this way? Did you consider (starting; continuing; ending) the class in a different way? Why/why not? 7. What other plans did you consider? Where did these plans come from? 8. What other factors influence your decisions with planning decisions for this topic? 9. How could you use (this representation or strategy) in a different way? Where did you learn to use it that way? Have you always used that? What experiences informed the way you use it now? 10. Where did you learn about the assessment strategies you used for (this topic)? 11. What other factors influence your decisions with teaching this topic? 12. In what ways have your ideas about teaching science changed since you began teaching? (Probe for sources of these changes.)

Appendix C

INTERVIEW PROTOCOLS

Interview Protocol for Preliminary Background Interview

The following questions were given to the participants at least one week prior to the interview so they could think about them ahead of time. These are the questions asked during the preliminary background interviews:

1. Describe your educational background (degrees earned).
2. Describe your professional teaching experiences (years; grade levels; courses).
3. Why did you decide to teach at community college?
4. Describe your professional experiences unrelated to teaching.
5. What are the main notions (points) of your teaching philosophy?
6. What is your purpose in science teaching at community college? Would it be different if you were teaching at 4-year University? Why? Why not?
7. What is your typical approach to teaching a science course?
8. What is the teacher's role in a typical science lesson?
9. What is the students' role in a typical science lesson?
10. How do you think students learn science best? Why do you think that?
11. Think of yourself as a science learner; how do you best learn science concepts?
12. How did you know when you learned science?
13. What do you consider most when you plan a lesson?
14. What do you think is/are the best way(s) to engage students in learning about science?

Interview Protocol for Strong and Weak Pre-Observation Interviews

The following questions were given to the participants at least one week prior to the interview so they could think about them ahead of time. These are the questions asked during the strong and weak pre-observation interviews:

1. What is the subject matter of the topic you will be teaching?
2. How comfortable are you with the subject matter for this topic? Where did you learn about this topic in your prior coursework or experiences?
3. How did you learn to teach this topic?
4. Where did you get your ideas for teaching this topic?
5. What are your purposes and goals for this lesson?
6. How did you decide on these purposes and goals?
7. What do you intend for students to learn about this topic?
8. Why is it important for students to know this?
9. How does (this topic) fit into the "big picture" of what students learn about science in previous science courses and later science courses?
10. Tell me about the materials you prepared. Where did these materials come from? What modifications did you make to existing materials?
11. Please explain any curricular programs you use for teaching this topic.
12. What factors influence your choices with planning decisions for this topic?
13. What are the difficulties or limitations connected with teaching this topic?
14. What do you plan to assess during your instruction? Why do you think it is important to assess this?
15. Where did you learn about the assessment strategies you used for (this topic)?

16. What do you think the students already know about this topic?
17. Why do you think that they may know that?
18. Where do you think they may have learned this already?
19. What misconceptions do students typically have when completing this lesson?
20. What do student difficulties with this topic typically look like? How do you know?

Interview Protocol for Strong and Weak Post-Observation Interviews

The following questions were asked after every video-recorded observation. These are the questions asked for strong and weak post-observation interviews:

1. How do you feel about today's lesson?
2. Any changes you think should be made? Why?
3. Any activities/items you will definitely repeat if you taught this lesson again? Why?

Interview Protocol for Video-Stimulated Interviews

The questions for this interview varied for each participant depending on the instructional strategies view in the selected video segments. Examples of questions included:

1. Why did you choose this image to represent the content?
2. Why did present the content in this way instead of another way?
3. Why did you ask these questions here?
4. Where did you learn this strategy?
5. Why did you answer this student's question in this way?
6. What types of things would you like to learn in professional develop?
7. What does an ideal professional development program look like for you?
8. Do you feel the administration of your community college supports your professional development?

Appendix D

COMPLETE TABLE OF DATA SOURCES FOR EACH PARTICIPANT

<table>
<tr><th rowspan="2">Participant</th><th colspan="2">Type of Data</th></tr>
<tr><th>Interview Data</th><th>Observation Data</th></tr>
<tr><td>David</td><td>• preliminary background
• strong pre-observation
• weak pre-observation
• strong post-observation 1
• strong post-observation 2
• strong post-observation 3
• strong post-observation 4
• weak post-observation 1
• weak post-observation 2
• video-stimulated</td><td>• strong observation 1 (50 m)
• strong observation 2 (50 m)
• strong observation 3 (2 h 40 m)
• strong observation 4 (50 m)
• weak observation 1 (50 m)
• weak observation 2 (22 m)</td></tr>
<tr><td>Jerry</td><td>• preliminary background
• strong pre-observation
• weak pre-observation
• strong post-observation 1
• strong post-observation 2
• strong post-observation 3
• strong post-observation 4
• weak post-observation 1
• weak post-observation 2
• video-stimulated</td><td>• strong observation 1 (50 m)
• strong observation 2 (50 m)
• strong observation 3 (2 h 40 m)
• strong observation 4 (50 m)
• weak observation 1 (1 h 15 m)
• weak observation 2 (2 h 40 m)</td></tr>
<tr><td>Sheila</td><td>• preliminary background
• strong pre-observation
• weak pre-observation
• strong post-observation 1
• strong post-observation 2
• strong post-observation 3
• weak post-observation 1
• weak post-observation 2
• weak post-observation 3
• video-stimulated</td><td>• strong observation 1 (1 h 15 m)
• strong observation 2 (1 h 15 m)
• strong observation 3 (2 h 40 m)
• weak observation 1 (1 h 15 m)
• weak observation 2 (1 h 15 m)
• weak observation 3 (2 h 40 m)</td></tr>
<tr><td>Vera</td><td>• preliminary background
• strong pre-observation
• weak pre-observation
• strong post-observation 1
• strong post-observation 2
weak post-observation 1
• weak post-observation 2
• video-stimulated</td><td>• strong observation 1 (2 h 10 m)
• strong observation 2 (15 m)
• weak observation 1 (2 h 40 m)</td></tr>
</table>

Appendix E

COMPLETE A PRIORI AND OPEN CODE BOOKS

Complete A Priori Code Book for Five Components of PCK

Code: OTS (Orientation to Teaching Science)

Subcode	Definition	Example	Frequency
4yr	Teacher should prepare students for transfer to classrooms at 4-year institutions	"what it's like at a four-year institution, a place that's . . . not as much as like here"	2
Care	Build rapport with student as a way to encourage student to increase their efforts in the class	"…I tended to excel in because I did feel like [the teachers] cared and they really did want you to be successful"	10
CK	Teacher's content knowledge is related to the type of instructional strategies they will employ	"So, if I have a harder topic, and in the previous semester, I gave the same lecture, and it just didn't flow right for me, I'll try to tweak it to find a way to do it differently."	3
CM	Classroom management issues	"I expect them to be on time, and to be respectful … strict policy with the whole phone thing"	4
Co Level	Teacher adjusts depth of detail in instruction based on course level	"I think that if it were to be taught in a lower biology class, I would probably not use as much scientific content, but just more conceptual."	8
Eng	Engaging the students will increase student learning	"I think if you kind of keep them on their toes, and they don't know what to expect, that they pay attention more."	27
Expert	Teacher should be an expert of the content they will be teaching	"if there is a subject I am not familiar with, I will make sure I'm the expert in it"	2
FAC Role	Teacher's role is to help facilitate student learning	"I describe myself as an assistant to them"	4
Info	Teacher's role is to deliver content information	"impart this to these students"	5
KE	Student learning increases if knowledge is connected to emotional understanding of topic	"this will get them more empathy and compassion because they understand more about the anatomy and physiology"	5

LS	Recognizes each student learns differently and has their own learning style	"also to learn their, what their individual styles because, you know, students learn differently"	12
SA	Student's attitude towards topic affects their learning	"they will come in with a preconceived notion, and they'll set themselves up for failure. And, that's kind of frustrating because it doesn't matter what you do."	4
Scaf	Example of instructor scaffolding the students' learning	"…have them assimilate new information with something they already know"	34
SCL	Student-centered learning	"I do the transcription dance … somebody's the ribosome, you know, and we have transfer RNA coming in, and we do high fives when we make a peptide bond."	10
SF	Student feedback helps to determine how material will be presented	"Feedback from students helps. So, I'm always asking them as I'm lecturing, "do you understand that?""	7
SOC	Society trends dictate science knowledge that should be learned	"people with an attention, behavior, or mood disorder have a very different way that they process things. If you're going to be in today's society, you have to learn how to get along with all kinds of people"	4
SR	Student is responsible for their own learning	"what [grade] they make in this class is up to them"	18
ST	Increased knowledge leads to a decrease in stereotyping	"maybe take the stereotype away from the syndrome or condition"	2
TACK	Teacher's attitude towards content knowledge affects instruction	"if you get a teacher that if it's not their favorite subject, they're not going to go into a lot of depth"	6
TIME	Amount of time spent preparing for a topic is dependent upon instructor's content knowledge	"how comfortable I am with it or how difficult it is for me to understand it, will influence how much time I put into it"	6

Code: KSU (Knowledge of Students' Understanding in Science)

Subcode	Definition	Example	Frequency
Diff	Instructor recognizes the topics that students typically have difficulty with	"look at immunity and there are so many different parts to it that it makes people gun shy"	21
Exposure	Instructor recognizes previous exposure of content for the student	"I think that because of the audience and them being in healthcare that some place in their job they've probably touched on one of the conditions"	29
Level	Instructor should tailor instruction to students' level of understanding	"this isn't going to be a lecture; this is your time to ask questions. So I usually do that with the higher level classes. But, with the lower level classes, it's more a structured "ok, let's go over chapter by chapter"	7
MIS	Instructor explicitly addresses common misconceptions	"are you depressed because it's snowing and you wanted it to be sunny? Or, are you depressed because you lost a parent? It's a very subjective term that's misused quite a bit."	9
MOT	Increased student motivation is related to increased learning	"the people that are motivated and are going to get good grades - do"	1
Need	Instructor recognizes that student needs additional help with particular topic	"I developed the like "oh, here's the high points of what we talked about today" notes"	4
Reteach	Instructor recognizes the need to explain a concept again in a different way	"ok, what I wanted to say that was in my head did not come out right." And, I need to think of another way to say that; otherwise, they're going to totally be messed up"	4
SQ	The student will ask questions about material they do not understand	"usually when somebody doesn't understand something, they'll ask a lot of questions"	2
SR	Student is responsible for their own learning	"sometimes, questions are just asked because … you didn't read that chapter before you came to class"	11
TIME	The amount of time it takes to gauge student understanding	"it takes about a week in class I think to gauge where your students are"	1

Code: KISR (Knowledge of Instructional Strategies/Representations in Science Teaching)

Subcode	Definition	Example	Frequency
AN	Instructor uses analogies to represent and explain content	“when you are talking about phagocytosis; if you talk about pacman”	14
App	Apply content through problem solving activities	“we do a lot of Punnett squares, you know a lot of problem solving”	2
Board	Only important ideas are written on the board	“if it’s written on the board it’s super important”	4
CK	Teacher’s content knowledge is related to the type of instructional strategies they will employ	“So, if I have a harder topic, and in the previous semester, I gave the same lecture, and it just didn’t flow right for me, I’ll try to tweak it to find a way to do it differently.”	7
Demo	Instuctor uses class demonstration to explain concept	“A lot of times I do demonstrations; and, I will ask for participants from the audience”	1
Draw	Students must draw and diagram concepts	“watch them draw”	1
EX	Instructor uses examples to explain concept	“I always try with a topic to find examples to relate either from like the media or something that might have happened in my personal life or just say, “oh, we’ve all had this happen to us.”	4
Explain	Students explain concept to increase learning	“I’m going to draw stuff up on the board, and you are going to explain it to me.”	12
HW	Assigns practice work to be completed at home	“we have the class and they do their homework that maybe – I’m hoping it will change their perception and give them some education and better skills”	3
Lab	Uses a lab activity to apply concept	“we have some slides that we’ll be using the microscope in lab”	7
Listen	Encourages students to only listen to lecture (no note-taking)	“sometimes when I do a hard subject, the first time I will say, “just listen; don’t take notes; don’t write anything down; just listen.” So that they can process it because sometimes they’re so busy trying to take notes and get down everything that you say, they miss the flow.”	2
LS	Instructor modifies instructional strategy based on students different learning styles	“I am applying all the methods that help the various learning styles”	3

LS Vis	Visual Learning Style is specifically addressed by instructor	"it is a flow diagram that shows you the steps that the reading goes through – the text goes through. And, most people are visual learners."	1
Mat	Available materials determines instructional strategy	"it's like maybe the materials available; they're just not as obviously available in the lab"	3
Mech	Instructor emphasizes the mechanisms to describe concept	"I try to focus them more on the mechanisms"	4
Mem	Instructor encourages rote memorization of concept	"I just tell them when there's something that they have to memorize"	3
Model	Students build models to explain concepts	"it's basically using the color beads . . . have them start from G1 and then replicate"	7
Move	Students physically act out concept to increase learning	"I do the transcription dance … somebody's the ribosome, you know, and we have transfer RNA coming in, and we do high fives when we make a peptide bond."	2
Online	Uses online labs/activities to provide additional content application	"there's some actually, some nicer online things you can do"	2
Refl	Instructor modifies instructional strategy based on reflection of previous experience teaching topic	"I might want to change something from how I've done it previously"	8
RL	Instructor uses real-life experiences and applications to explain content	"I think if a student can relate a personal experience, it makes the information easier for them to remember"	32
Size	Number of students in a class affects type of instructional strategy	"you can't individualize to that many students; you just have to sit up there and lecture"	1
SF	Student feedback determines type of instructional strategy	"often I would hear from students you know if they didn't call something three different things"	2
Time	Amount of time determines type of instructional strategy	"it takes time to draw . . . so that way I can move quicker through the material, if the stuff is already up there"	15
TSS	Topic determines the specific teaching strategy that is used (topic-specific strategy)	"you kind of have different teaching styles, I think, depending on the topic."	8
VerbRep	Instructor uses verbal representation to describe concept	"I also type up notes that's kind of a summation of what we've talked about so they have that"	8

VisRep	Instructor uses visual representation to explain concept	"I'm a very visual person so I draw a lot on the board. I'll use powerpoint if there's a lot of pictures and I don't feel like I have enough time to draw everything."	28

Code: KSC (Knowledge of Science Curriculum)

Subcode	Definition	Example	Frequency
HC	Horizontal curriculum: Instructor recognizes that understanding one topic is necessary for learning of next topic	"since inflammation is the beginning for a lot of different diseases for them to understand the process for how it works correctly will help them understand where it messes up at different points"	20
Pub	Uses publisher materials from textbook to design course curriculum	"I used the chapter in the Braun and Anderson pathophysiology book; the third edition that we're using for class."	27
SLO	Student learning outcomes are key to curriculum design	"my student learning outcomes for this class are centered around immunity, both innate and adaptive"	2
Teach	Instructor determines topics for course curriculum	"I'll use [powerpoints]. I'll try to kind of edit them a little bit, try to get rid of things"	15
VCA	Vertical curriculum (after): did not learn a concept in a previous course in preparation for current course	"we touch on the limbic system in A&P one. So, they're familiar with the fact that it's associated with moods"	8
VCB	Vertical curriculum (before): instructor understands how current course is a pre-requisite and fits into other programs	"most of the students that take pathophysiology are either in the nursing program or they are trying to get into the nursing program. And, it gives them a good foundation for their nursing classes."	14

Code: KA (Knowledge of Assessment of Science Learning)

Subcode	Definition	Example	Frequency
APP	Uses application of content to gauge student learning	"I think when you have really learned and grasped the material is when you can apply it and come out with the same results"	4
FACE	Instructor gauges student understanding by reading facial expressions	"sometimes they'll give deer-in-headlights looks; so, I'll be like, "should we go over it again?"	18
FORM	Instructor uses formative assessment technique	"I'm always asking them as I'm lecturing, "do you understand that?"	31
PROBE Q	Instructor asks probing questions to uncover student understanding	"And, sometimes, I might say, "who is this? What do they do? What does this mean?" And see if they can mirror it back to me."	17
SUMM	Instructor uses summative assessment technique	"I don't know if I can assess that until after they take the test, and see how successful it was"	25

Complete Open Code Book for Sources of PCK Development

Code	Definition	Example	Frequency
BIO	Use of biology websites	"There's one I think it's called The Biology Project"	2
Int	General search of internet sites	"I usually have google open because sometimes they use words that you are not familiar with"	11
Med	Use of online medical sites	"I looked up a lot of the terminology because I wasn't familiar with it. So, just different medical sites"	4
MOD	Model instruction after teachers from their own college courses	"the teachers that I had that I've kind of emulated my teaching methods after"	9
OBS	Observation of other instructors in the classroom (in person)	"Working with other instructors"	8
PD	Professional development activity	"Going to seminars"	7
PE	Personal experiences in other informal settings	"Helping my son with his homework"	3
POD	Listens to podcasts	"I'll listen to podcasts"	1
REF	Uses reference textbooks other than the course text	"if I don't understand something, I do have a lot of reference books"	4
SF	Student feedback used to redesign instruction	"Feedback from students helps."	4
TB	Course textbook	"First, I like to read the textbook just so that I see what the student is reading"	17
TE	Trial and error	"it was trial and error because I knew I was comfortable and I understood it, but it was like, 'ok, how can I [teach it]'	17
Teach Exp	Teaching Experience	"I probably know more . . . about what I'm teaching now than I did"	5
Vid	Online videos about topics	"if I find a video that really brings things together like in ten minutes … I always put that on my site"	10

Appendix F

COMPLETE INTERACTION CODE BOOK

Interactions with 2 Components	Frequency
OTS – KSU	8
OTS – KISR	15
OTS – KSC	1
OTS – KA	8
KSU – KISR	6
KSU – KSC	2
KSU – KA	7
KSC – KA	1
OTS – KSU	8
KISR – KA	8
KISR – KSC	0

Interactions with 3 Components	Frequency
OTS – KSU – KISR	1
OTS – KSU – KSC	1
OTS – KSU – KA	2
OTS – KISR – KSC	1
OTS – KISR – KA	1
OTS – KSC – KA	0
KISR – KSU – KSC	1
KISR – KSU – KA	2

Interactions with 4 Components	Frequency
OTS – KSU – KA – KISR	0
OTS – KSU – KA – KSC	0
OTS – KSU – KISR – KSC	0
OTS – KISR – KSC – KA	0
KSU – KA – KISR – KSC	0

Interactions with 5 Components	Frequency
OTS – KSU – KA – KISR – KSC	0